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Investigating the Qualities of Raw Lithic Material and the Selection Pressures of Lithic Materials from the Gunflint Formation, in Ontario Canada.

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Master of Environmental Studies: Northern Environments and Cultures

Lakehead University

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Submitted to the Faculty of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Masters of Environmental Studies in Northern Environments and Culture

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ABSTRACT

The study of stone tools in archaeology has advanced considerably in recent years, from the early ideas of what makes a stone anthropogenically modified to using advanced spectroscopic techniques to help determine ancient trade networks and group relationships. However, there is a gap in our understanding of how the raw material behaves during manufacture and the attributes that make it favorable for selection at a quarry. There are many physical characteristics and various properties, including cultural aspects that need to be examined before researchers can further develop our understanding in these areas. Using the material quarried from the Gunflint Formation in Northwestern Ontario, Canada as a case study, the presented research aims to address some of these gaps in our understanding. In order to achieve this goal, new applications for testing were developed and statistical analysis was employed to determine the potential usefulness of each test. In addition, this study placed the data collected into a framework to answer a specific question related to the archaeological sites; what are the desirable traits in the Crane Site bifaces and are they manufactured from material sourced from one of the local quarry sites? Moreover, an effort was made to source by traditional and chemical techniques, these artifacts to specific outcrops within a single geologic formation. Overall, there was some success achieved at least in terms of using these methods as a sorting method for organizing large samples, building a local lithology of the raw material and, sourcing materials to specific outcrop locations.

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Chapter 1

Introduction

The papers presented in this thesis represent an attempt to understand the factors that influence the selection of lithic raw material in the study region of the northwestern shores of Lake Superior. More specifically deriving from the Gunflint Formation on the Canadian side of the border with Minnesota. The temporal focus of the study will be the Paleoindian period, which began around ~9500 YBP in the area of study, and blended into the Archaic period around ~7000 YBP (Dawson 1983, Julig et al. 1990). An attempt was made to document the many different varieties of raw materials that can be found at two known lithic quarries sites in the region. Furthermore, five bifaces from a local cache were compared to these reference samples with the aim of identifying the traits of a desirable lithic material that was selected, for the manufacture of these specific stone tools. The goal of the research methodology was to investigate the utilitarian and cultural values of the raw material held by the ancient artisan(s) who manufactured them into bifaces. Also, an attempt was made to investigate if this lithic material could be sourced to a specific outcrop rather than just the geologic formation. Each chapter will detail the specific research investigated and provide some context into the study in general.

Lithic materials are a fundamental component of prehistoric archaeology; their resistance to natural taphonomic (decay) processes ensures, in many cases, their presence in the archaeological record is common. The Boreal Forest of Northwestern Ontario, where the presence of podzolic (acidic) soils dramatically breaks down organic artifacts, emphasizes the importance of lithics at aceramic sites (sites without the presence of ceramic artifacts) (Hamilton 2000). The current approach to identify and describe lithic materials in Northwestern Ontario has largely remained the same since the inception of archaeological research in the area during the 1950's. This strategy has been to describe lithic materials with non-systematic, superficial and subjective descriptions. While, there have been detailed studies within the area, these tend to focus on provenience studies, tool morphology or on the effects of heat-treatment on lithic materials (Bennett 2015, Markham 2012, Norris 2012, Wendt 2003, Borradaile et al. 1993, Ross 1979, Fox 1975). The situation has left researchers pondering questions related to the quantifiable characteristics of the raw material itself. Within the larger context of archaeological research, there are many other areas where this trend is paralleled.

To offer one suggestion as to why this trend occurs, at least in the study region of Northwestern Ontario, is that the predominant focus of archaeological enquiries are restricted to a cultural resource management framework (Markham 2012, Hamilton 2000). This is likely because detailed descriptions of the macroscopic features of lithic materials, to the extent that has been investigated here, is not fiscally possible for consulting firms. Thus, the simple description of what the material looks like is often stated in consulting reports without much consideration to the minutia of the range of appearance characteristics, which, can provide insight into many attributes that could help archaeologists better understand the ancient past though lithic raw materials.

1.1 The Gunflint Formation

The Gunflint Formation is a member of a group of sedimentary and meta-sedimentary formations, which, share similar characteristics in terms of chemistry and deposition. These formations collectively are referred to as Banded Iron Formations and typically date to the Precambrian Era (Goodwin 1956; Awramik and Barghoorn 1977; Pufahl and Fralick 2000;

Fralick, et al. 2002; Jirsa et al. 2011). Banded Iron Formations are chemically very similar containing abundant amounts of iron-based, carbonate, and silicate minerals (Floran and Papike 1978). The chemistry of Banded Iron Formations is a reflection of the chemical makeup of the marine environment during the Precambrian Era, where the marine environment was composed of iron-rich water. This iron-saturated water was the habitat for the earliest forms of life on earth - cyanobacteria (Goodwin 1956; Awramik and Barghoorn 1977; Pufahl and Fralick 2000; Fralick, et al. 2002; Jirsa et al. 2011). These Precambrian organisms began to produce oxygen as a by-product of photosynthesis. As a result, the oxygen that was produced reacted with the iron in the ocean, which was in solution, and began to oxidize and precipitate iron-based minerals such as magnetite and hematite. These iron rich minerals collected on the ocean floor. Ocean currents manipulated and worked these iron-rich sediments, which formed the unique stratigraphy of a dynamic marine environment where calm water and turbulent water events are both represented (Pufahl and Fralick 2000). The Animikie Basin is the term given to the marine environment where the Banded Iron Formations in the Lake Superior region developed it includes the Gunflint Formation which is the local Banded Iron Formation (Pufhal 1994).

The Gunflint Formation represents the ancient marine shelf of the Animikie Basin. The marine depositional environment is reflected in the sedimentary structures observed in the stratigraphy of the Banded Iron Formation. Iron rich sediment that was reworked into granules, reflects the repetitive pattern of water levels, increasing and decreasing along a south facing marine shelf (Pufhal 1994, Pufahl and Fralick 2000). This is evident in the lithographic sequence of the Gunflint Formation where taconite, which is a grainstone, and shale/mudstone layers are deposited in alternating sequence. The interpretation is that the finer grained materials, i.e. shale/mudstone, represent periods of deposition in deep calm waters and coarser-grained materials represent periods of deposition in shallow turbulent waters (Pufhal 1994, Pufahl and Fralick 2000). These sequences are repeated across the various other Banded Iron Formations deposited in the Animikie Basin, which are located in the United States specifically Northern Minnesota and Michigan (Pufhal, 1994).

The two formations most pertinent to the discussion of this study are the Masabi (Range) and Gunflint Formations. Both formations would have been considered one continuous formation if it was not for the large igneous intrusion called the Duluth Complex (Figure 1), which bisected the formations during the Mid-continental Rift event, which occurred during the middle period of the Precambrian Era (Mesoproterozoic Era). The Duluth Complex introduced post-depositional changes in both formations, which was the result of contact metamorphism (Floran and Papike 1978, Pufal 1994, Pufahl and Fralick 2000). The metamorphic alteration led to the development of particular zones of chemical alteration, which differ in their proximity to the igneous intrusion both the Masabi and the Gunflint Formations (Floran and Papike 1978). Although both the Gunflint and Masabi Formations are similar, they differ in one key aspect essential to the discussion of ancient stone tool manufacture. The Gunflint Formation has the higher silica content of the two Banded Iron Formations, a fact that has implications for the availability of high-grade lithic raw material on the Canadian side of the Gunflint Formation (Goodwin 1956).

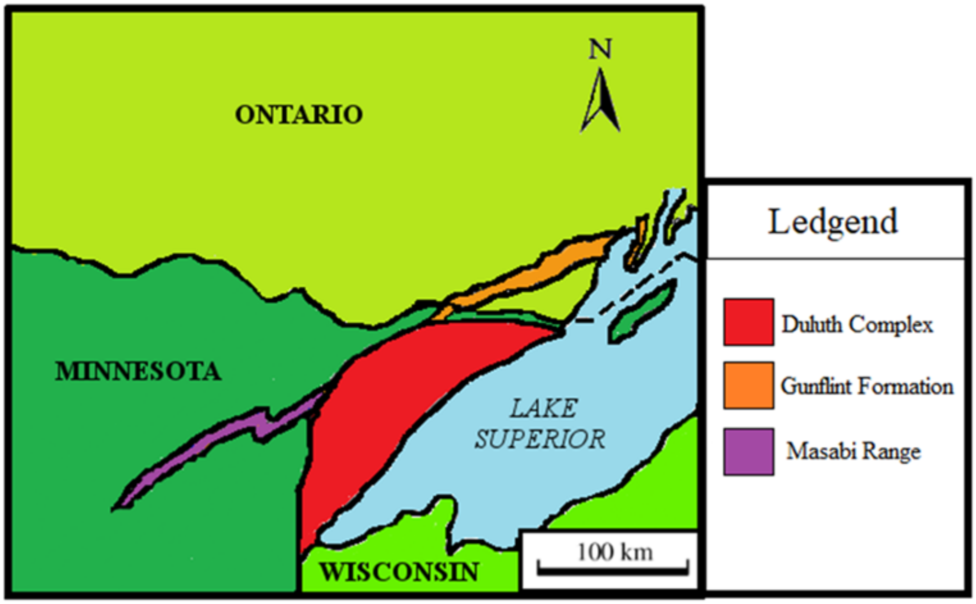

Figure 1 *A Geologic Map of the relevant bedrock formations on the Northwestern Shores of Lake Superior after Schmidt & Williams 2003*

The specific lithostratigraphy of the Gunflint Formation can be briefly summarised as having two major members, a lower and upper member. The lowermost member is a conglomerate; known as the Kakabeka Conglomerate and is largely made up of pebbles of granitic rocks, quartz, basalt, and metamorphosed basalt (Pufal 1994, Pufahl and Fralick 2000). In addition but to a lesser extent, there are thin bands of sandstones (less than 1m in thickness) which are present in the lower member (Pufal 1994, Pufahl and Fralick 2000). Appearing above the sandstone layer are silica-rich grainstones, which occur with alternating bands in some outcrops (Figure 2). Also within the lower member are stromatolitic cherts, which overlay the conglomerate and mark the boundary into the upper member (Pufal 1994, Pufahl and Fralick 2000). These stromatolitic cherts were used for the manufacture of stone tools (McLeod 1981). However, the use of this material seems less than other Gunflint materials such as taconite, as evidence of formal tools from this material are rare. The upper member is largely made up of sections of alternating bands of shale/argillite/slate and thick sections of cherty grainstones. These cherty grainstones specifically the varieties of taconite were selected for the manufacture of stone implements (Figure 3, Figure 4). Other components, which overlay the upper member, are sections of a breccia made up of the sediment and the debris, which mark the Sudbury Meteorite Event (Jisra et al. 2011). Finally capping the formation in some areas are the igneous intrusions of both the Logan Intrusions (various dikes and sills) and the Duluth Complex. However, the majority of the upper member is capped by another separate formation known as the Rove Formation, which is largely made-up of shale (Pufal 1994, Pufahl and Fralick 2000).

Figure 2 *An example of an outcropping of the lower member of the Gunflint Formation.*

Figure 3 *The upper member of the Gunflint Formation*

Figure 4 *The upper member of the Gunflint Formation with researchers collecting samples*

1.2 The Paleoindian Period

The Paleoindian period in the Thunder Bay area began shortly after the retreat of glacial ice, which covered the area around 9500 YPB (Fox 1975, Ross 1979). The retreat of glacial ice also exposed much of the Gunflint Formation, which provided suitable lithic material for the manufacture of stone tools (Phillips 2004 Dyke 2003, Dawson 1983, Julig et al. 1990). Culturally, the ancient people, who followed the retreating glacial ice into the Thunder Bay area during this period are known by their stone tools as members of the Lakehead Complex (Fox 1975, Ross 1979). The Lakehead Complex can be characterized by lanceolate projectile points, which exhibit basal edge grinding, side edge grinding and parallel oblique flake scars, and with archaeological sites having a strong association to the shorelines of glacial Lake Minong (contemporary Lake Superior) and the Gunflint Formation (Fox 1975, Ross 1979, Fox 1980).

1.3 The Archaic Period

The Archaic period in the Thunder Bay area is less understood and dates from around 7000 YBP. There is a gap in the literature regarding this period, and the transition between the Paleoindian and the Archaic period is in some cases blurred (Hinshelwood 2004). The ambiguity between the periods is largely due to the slow development of soils in the region leaving cultural strata difficult to determine, and often Paleoindian sites are re-occupied by Archaic groups, but most importantly many of the Archaic Sites are now under Lake Superior due to the rise in water levels to the contemporary depths (Hinshelwood 2004, Hamilton 2000). Without formal tools or accurate radiocarbon dates researchers often determine the age of sites with relative dating methods, which often involve the elevation of the shorelines of contemporary Lake Superior. However, from what we do know about the Archaic period, we begin to see the appearance of a more diverse assemblage of material culture, with fishing implements and copper tools appearing, and in terms of lithics there appears to be a shift from quarried materials to nodular cherts (Hamilton, 1996). Projectile points begin to show both stemmed and notched bases and their overall size decreases (Dawson 1983, Julig et al. 1990). With respect to site locations and as previously mentioned in some Paleoindian sites, some are re-occupied by Archaic groups, and we see an overall northward expansion into areas recently deglaciated (Hamilton 2000, Hinshelwood 2004).

Chapter 2

Using a Force Gauge for the Analysis of Raw Lithic Material from the Gunflint Formation, Thunder Bay ON. Canada

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Abstract:

Understanding what makes a good raw material for the manufacture of stone tools has been a question asked by many novice flintknappers who want to study the subject. Often the trial and error approach along with the help of a guiding tutor helps enlighten the novice to better understanding. However, this situation often creates somewhat of a subjective understanding of the practice. The knowledge is somewhat internalized and difficult to articulate without actually practicing the ancient art. For the purposes of scientific research, it becomes more apparent and frustrating, teasing out the wealth of quantifiable data from a subjective process of manufacture. This study attempts to apply a modified methodology for assessing the qualities of a material while it is pressure flaked, using a qualitative testing apparatus. The raw lithic material being tested is from a local lithic formation in Northwestern Ontario and is part of a growing body of literature focused on trying to better understand the selection pressures faced, while selecting raw materials, by ancient peoples at quarries in the area.

Keywords: pressure flaking; lithics; quarry sites; stone tools, technology

1.1 Introduction

Experimental replication of archaeological stone tools has provided insights into the archaeological lithic technology of early North America. One well-known experimental archaeologists of the current era was Don E. Crabtree who provided many technical terms and concepts from his work in the late 1960s and into the 1970s (Crabtree 1975; Crabtree 1970;

Crabtree and Davis 1968). Others have built upon his research in the field, including George Odell, John C. Whittaker and Bruce Bradley (Odell 2012; Odell 1994; Odell 2001; Whittaker 2010; Bradley 1991; Bradley 1993; Bradley 1975; Bradley 1982). There have also been significant contributions to our understanding of techniques from people who may not be full-time academics but who practice this craft as either a hobby or a way of life and have taken the time to show others their techniques and knowledge (Eren et al. 2010).

Flintknapping is a complex craft and understanding the nuances requires significant experience. When knowledge is acquired, however, articulating the process and identifying the challenges is sometimes highly subjective. Descriptions of materials can often be ambiguous. In many cases, controlled experimental techniques fail to replicate the flintknapping process. Moreover, these controlled mechanical-experimental techniques are difficult to reproduce or fail to integrate with a well-articulated archaeological hypothesis (Eren et al. 2016; Magnani et al. 2014; Dibble and Rezek 2009; Dibble 1997; Speth 1981). Flintknappers need to understand both the manufacturing process for a specific lithic typology and the variability of the physical properties of their chosen lithic raw material. That understanding can be supported by scientific analysis of the raw material. Successful progress in this field of research requires a careful balance, between rigorous scientific analysis and the accurate imitation of techniques that those who practice this craft, believe were used by ancient manufacturers. This research presents the preliminary findings of a methodology that aims to provide a reproducible testing procedure for measuring the force required to produce flakes in lithic raw materials using an analogy to pressure flaking.

1.2 Samples

The Thunder Bay region in Northwestern Ontario has many sites with stone artefacts dating to the Paleoindian and Archaic periods. The stone tools were manufactured from raw material found in the Gunflint Formation (Steinbring 1976, Fox 1977, Julig 1984). This is a very large outcrop of Precambrian sedimentary rock, which extends from just west of Gunflint Lake on the Minnesota and Ontario border for about 350 km northeast continuing under Lake Superior. The formation includes layers of siliceous grainstones (taconite), fossilized stromatolites, iron rich “cherty” grainstones and shale/slate (Pufahl and Fralick 2000). This complex geology means that as a source of raw material for stone artefacts, it is variable in composition. Two ancient quarry sites within this formation, the Shuniah and Cummins Quarries, were selected as the source for samples in this trial.

1.3 Sample Preparation

Using a lapidary saw, raw material samples were cut into blocks with the approximate dimensions of 30mm long by 10mm thick by 10mm wide. After cutting, the cut sample blocks were carefully scrutinized, and any blocks with weathered surfaces or apparent flaws were excluded as a reference sample. One corner of the cut sample blocks with a 90° angle to the adjacent face was carefully selected as the flaking platform.

1.4 Apparatus

The selected equipment is similar to that described by Dibble and Rezek (2009) with modifications to suite availability of materials and budget. The original application of this method was to understand how flakes form within a uniform material using glass as the medium.

The modified apparatus consisted of an analogue push-pull force gauge with a measurement range of 0 to 300N, fixed to a crankshaft which could very slowly move the force gauge up and down (Figure 5). To create the flakes, attached to the force gauge was a pressure point consisting of a custom machined copper bit, which terminated in a point of 0.05 ± 0.01mm diameter. The copper tip was selected as a result of initial tests, where it was observed that the original steel bits supplied with the force gauge were sliding off the surfaces of the sample blocks without producing a measurable flake. With the copper bit, there was far more friction between the tip and the sample blocks allowing the tip to grip the surface and remove a flake.

The prepared flaking platform served as the initial point of contact for the tip of the copper bit. To measure the striking force consistently, the initial point of contact was uniformly set to be 1mm from the vertical edge of the sample block with the force applied slightly towards the center mass of the block, in an effort to control the depth of the flake created from the platform.

A drill press angular vice was used to hold the sample blocks. This vice could be adjusted relative to the copper bit but when the pressure was applied it was found that the sample could move downwards, producing an angular adjustment that caused the copper bit to slide off the platform edge and it did not detach any material from the sample block. As a result, the method was adapted, whereby a piece of leather was used to act as a high friction but flexible interface between the vice and the block, providing more grip on both surfaces (Figure 5). Holding the sample blocks in a piece of leather had the added benefit of providing a more natural replication of the manual pressure flaking technique. As the cut sample block was partially hanging outside the jaws of the vice, the copper bit was able to tilt the block downwards until either the tension of the leather held it firmly, or sufficient force was applied to remove a flake. Compared to previous research methodologies, this adapted method including the copper tip for more grip on the platform face and holding the whole sample block in leather, more accurately simulated the manual flaking process.

1.5 Flaking Procedure

Pressure to create the initial flake from each block, i.e. the first flake removed from each sample, was applied at 1mm from the prepared cut edge of the sample block. After the initial flake was removed, each block was moved laterally so that the copper tip was at the edge of the initial flake scar and that location served as the new platform for the removal of the next flake. This lateral repositioning was repeated for each subsequent flake removal. If the edge was crushed which was rare, and an initial flake was not removed, that block was excluded from the study. It is well established that when striking a brittle or cryptocrystalline solid material, a cone of force (Hertzian cone) creates waves that propagate as the shock waves move through the material in a characteristic pattern that is observed on the flake surface. The concentric waves left on the fracture face are part of a Hertzian cone generated bulb of percussion. To be included in the results, each flake had to have an observable bulb of percussion. Five flakes were removed from the blocks that comprised one original reference sample and the average force required to remove each flake was calculated. The minimum force required to detach one of those five flakes from each original sample was also noted. After five samples were tested, the copper bit was changed, to avoid the use of blunt tips. Ideally, these copper bits could be changed after each test but, this would have been too expensive for this preliminary study since they were custom manufactured.

In addition to the measurements of force, the angle of detachment was also calculated. Using the results from the five successful flakes from each sample an average for each raw material sample was calculated and recorded (Table 1). The angle of detachment was the angle to which the flake was removed; this was measured using a digital protractor.

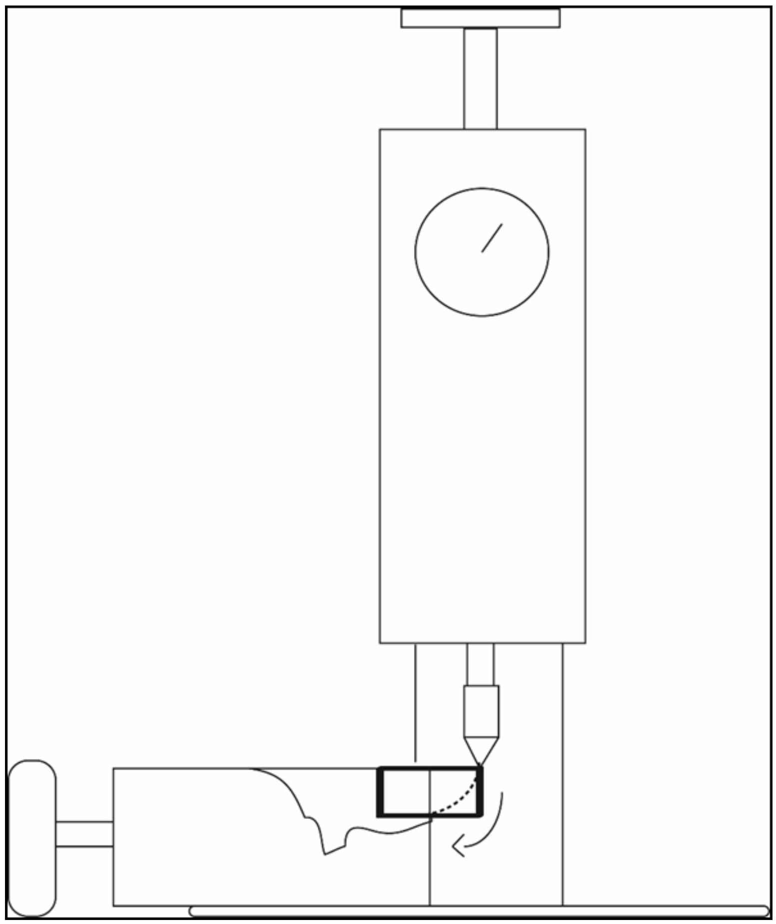

Figure 5. *A diagram showing the set-up of the apparatus*

1.6 Results

In order to understand the amount of force required to flake the test samples, the minimum amount of force needed to remove a flake was noted, in addition to calculating the average force used to produce the five flakes from each sample (Table 1). Excluded from the results and analyses are those blocks where the applied force crushed the edge of the block. The occurrence of edge crushing was rare and usually occurred with improper setup due to the placement of the block into the vice. Also, all flakes had to have an observable Hertzian cone to be included in the results. It was observed that the successful flakes detached at an angle of 60° to 70°, relative to vertical. The detachment angle seems to reflect the ideal, less than 90° angles in relation to the platform of a core, which most flintknappers try to use for the detachment of flakes (Magnani et al. 2014; Dibble and Rezek 2009; Speth 1981). For this trial, in all recorded cases of successful flakes, the fracture travelled straight though the cut sample.

The average force to create a flake varied from 110 to 308N, with a mean of 195N (Table 1). There was a wide range in the minimum amount of force required to remove a flake, from 50N to 290N (Table 1). The range of the minimum amount of force required to create a flake from the material collected from the Shuniah Quarry was 50N to 127N (Table 1). At the Cummins Quarry Site the range of the minimum amount of force required to produce a flake was less variable possibly due to the smaller number of samples tested, and the average from 60N to 225N (Table 1). While the average of all the samples tested calculated independently was lower at 110N.

***Table 1**. Measurements of force and angle of detachment*

Sample	Site	Minimum Force (N)	Average Force (N)	Angle of Detachment
ON-SM-03	Shuniah	60	132	60°
ON-SM-05	Shuniah	100	212.5	64°
ON-SM-08	Shuniah	50	165	65°
ON-SM-14	Shuniah	100	218.33	70°
ON-SM-15	Shuniah	125	250	63°
ON-SM-17	Shuniah	140	209	72°
ON-SM-19	Shuniah	50	175	62°
ON-SM-20	Shuniah	55	198	66°
ON-SM-21	Shuniah	90	166	61°
ON-SM-22	Shuniah	100	168.25	63°
ON-SM-23	Shuniah	125	229	67°
ON-SM-24	Shuniah	200	216	61°
ON-SM-25	Shuniah	175	275	70°
ON-SM-26	Shuniah	225	225	66°
ON-SM-27	Shuniah	125	212	73°
ON-SM-28	Shuniah	100	110	65°
ON-SM-29	Shuniah	90	183	57°
ON-SM-30	Shuniah	75	183.7	80°
ON-SM-32	Shuniah	125	175	70°
ON-SM-34	Shuniah	75	117.5	62°
ON-SM-35	Shuniah	175	233.33	60°
ON-SM-36	Shuniah	125	267	64°
ON-SM-37	Shuniah	275	282	66°
ON-SM-39	Shuniah	190	218.75	54°
ON-SM-40	Shuniah	135	217.5	71°
ON-SM-43	Shuniah	100	135	63°
ON-SM-45	Shuniah	75	161.66	68°
ON-SM-48	Shuniah	75	177	69°
ON-SM-49	Shuniah	225	256	70°
ON-SM-50	Shuniah	290	308	50°
ON-SM-51	Shuniah	75	168	70°
ON-SM-53	Shuniah	125	150	60°
ON-SM-56	Shuniah	75	150	62°
ON-CS-01	Cummins	75	162.5	64°
ON-CS-02	Cummins	100	200	56°
ON-CS-03	Cummins	225	281.25	67°
ON-CS-04	Cummins	60	112	66°
ON-CS-05	Cummins	60	129.16	61°
ON-CS-06	Cummins	100	193.75	69°
ON-CS-08	Cummins	125	181.25	72°
ON-CS-09	Cummins	150	227	67°
ON-CS-10	Cummins	100	196	63°
ON-CS-12	Cummins	100	130	61°

1.7 Discussion

All the samples tested were selected because, visually, they were considered typical of the types of material from the Gunflint Formation, which had been used by ancient manufacturers to make stone tools, based on the evidence found in some of local ancient quarry sites. As heat-treatment of lithic materials was not a practice in the study area, all materials were not heat treated in this study (Borradaile et al. 1993).

The original application of this equipment was to test flaking of uniform media, i.e. glass. Modifying this method to measure forces within a heterogeneous material proved challenging. It was necessary to control some of the variables related to lithic raw materials by excluding sample blocks with inherent flaws (cracks, vugs, cortical surfaces, etc.). The method requires the careful setup of uniform flaking platforms for all of the test sample blocks and maintenance of a constant initial flaking angle. With most of these challenges adequately addressed, the modified method provided some excellent results.

The ideal flake properties include a bulb of percussion created by a Hertzian cone of force and the flake shape resembles one half of a “clam shell”. However, variation was observed in the appearance and properties of the removed flakes, between different test samples in this study, although the well-defined bulb of percussion was achieved in most cases. Some samples tended to produce deep plunging flakes, and it was noted that they required a higher level of force to be applied, for any flaking to occur. In some specific instances a material sample block which looked typical upon external inspection would flake in a very different and less desired manner. Often these flakes would possess the characteristics of a flake which is detached at an angle of closer to 90º not by pressure flaking but by percussion (Cotterell and Kamminga 1987). The cause of this type of detachment may be a result of the characteristics of a particular type of material or a hidden flaw in the sample block or possibly from some inconsistency of the flaking apparatus.

The copper bit needed to be changed regularly as the sharpened tip would quickly become blunt. The lack of strength in the tip and its rapid deterioration was due to the chosen method of preparation. Copper when hammered, becomes harder, but these tips were cut from a bar by machining on a lathe. This rapid blunting of the tip would have resulted in less force being focused on a specific point. While this may not have been the cause of atypical flakes demonstrating the characteristics of a steep angle detachment, it could be a contributing factor because the blunt tip tended to slide off the platform. Any reduction in force focused on a specific point will alter the displacement of the tip relative to the block of sample material, which could have caused angles to change.

Flakes, which resembled those that are typically manufactured at a steep 90° angle, could be characteristic of the material itself since the physical properties of the material play a central part in the propagation of flakes. This provides an interesting point of discussion concerning the process of flintknapping, suggesting the optimum angle for the detachment of flakes may be different for each particular material. The potential for differences was represented in the research results, by the wide variation in test results for this material sample set from the same raw material. This variation has implications for the complexity of the skills our ancestors required to practice the craft of flintknapping.

To avoid the necessity of continually adjusting strike angles to remove the desired flakes, ancient flintknappers preference may be given to lithic raw materials that are predictable and require less technical understanding (at least when learning the craft). The successful transmission of craft knowledge also requires some degree of predictability and a good understanding of the material being manipulated. Predictability supports the repeatable production of stylized flakes that ultimately leads to the creation of useful tools.

Analysis of the results also identified considerable variation in the relationship between the minimum force required to remove a flake and the average amount of force required by that sample. The cause of this difference could be due to unseen flaws in the sample, mineralogical differences within the material, errors in the platform setup or blunting of the copper tip. However, it was noted that the initial flake removed from a sample block consistently required a significantly higher amount of force. Each additional flake removal then required less force as the applied pressure followed existing flake scars It is likely that because there was a prepared platform before the initial flake was removed, less force was required to remove these, and each of the successive flakes were not struck along an artificially created material face.

These observations are compatible with the accepted conventions of flintknapping, and are common knowledge of the modern flintknapping community. Quantification provides a reference point to compare these physical characteristics across different lithic raw materials and articulates the subjective but commonly held beliefs of flintknappers. A controlled methodology provides a framework for reliable, reproducible results that can augment previous practical research approaches.

There were some important principles established while using this methodological approach. Firstly, the importance of cold hammering to manufacture the copper bit. This should be incorporated into future studies to reflect more accurately the features of manual archaeological flintknapping tools. Secondly, it was noted that the results from the two quarry sites were different even though the samples were considered to be visually similar. This observation implies unique properties for lithic raw materials within a particular outcrop and between outcrops; so the method provides a tool to investigate reasons for particular outcrop selection by ancient flintknappers. Understanding a particular lithic raw material in an archaeological context is important. The argument can be made that for consistency of a raw material, ancient peoples may have preferred specific quarry sites over others within a particular geological formation, and again, this methodology provides a practical technique to acquire repeatable data for a baseline assessment of each type of raw material within a formation.

1.8 Conclusion

This preliminary research presents findings that may not necessarily reflect the utility of this method across multiple sites and/or geographical regions, as each geological formation has its own unique lithology. The samples for this research were collected from two known ancient quarry sites within the Gunflint Formation. These samples can be used to demonstrate how this methodology could be applied to understand the properties of any materials that have been used in the past for the manufacture of stone tools. The specific results may not necessarily reflect those from other sites and geographical regions because each geological formation comprise materials with their own unique characteristics. However, this methodology can be applied to better understand other geological formations and the properties of their lithic raw material, contributing to our understanding of stone tool manufacture.

However, this research also identified some of the challenges with the application of this methodology and the need to investigate alternative methods to fabricate harder copper bits. The method provides a cost-effective and more scientifically controlled approach to the study of flintknapping and investigating the physical characteristics of lithic raw materials. It also provided a more realistic approach to the ancient manual manufacturing simulation of the flintknapping process for controlled analysis. Using the flaking apparatus, consistent and characteristic lithic flakes were detached from a raw material core providing a better sense of how a material responds under the pressures required for flintknapping. Understanding the interaction between the manufactured copper bit and the flaking process could be investigated further. However, the methodology applied did provide insights into the lithic raw material and the variation of its qualities. This study provides a better understanding of how flakes from different samples of the same geological formation were manufactured. Being able to demonstrate that two macroscopically similar materials from two different outcrops may behave differently, supports the argument that ancient hunter-gather groups may have targeted specific sites to produce more consistent and repeatable stone-tools. Overall, this method provides a better understanding of the intricacies of flintknapping by measuring the forces used in a realistic simulation of typical manual manufacturing techniques.

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Chapter 3

Combining Multiple Methodologies to Identify Characteristics of an Ideal Raw Material Quarried From The Gunflint Formation Thunder Bay ON

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Abstract:

The selection pressures facing ancient flintknappers in the area of Thunder Bay, Canada, has not yet been fully evaluated at least in terms of the local area. The reason for this gap in our understanding is because most of the archaeological excavations in the area are conducted in a commercial capacity, which limits the extensive implementation of academic research. This research attempts to identify the macroscopic qualities of a raw lithic material and compare this to the physical qualities of the material in an effort to establish a quantitative preliminary baseline of the local lithology of raw stone materials. With this baseline a better understanding of what qualities of a lithic raw material might have been determining factors for their selection by ancient artisans at a quarry location.

Keywords: lithics; quarry sites; stone tools, macroscopic characteristics

1.1 Introduction

Lithic materials are a fundamental component of prehistoric archaeology. Their resistance to the natural taphonomic decay processes ensures their presence in the archaeological record is common (Odell 2012). In the boreal forests of Northwestern Ontario where the presence of acidic podzolic soils completely breaks down organic artefacts, the importance of lithic artefacts is amplified especially at aceramic sites of the early Holocene (Hamilton 2000).

In the region of Thunder Bay, Ontario, it has been well established that many sites dating to the Paleoindian period are associated with the former shoreline beaches of Lake Minong (Phillips 1988; Hamilton 2000). However due to lake level changes of the Houghton low phase of contemporary Lake Superior many archaic sites are now underwater (Phillips 1988; Hamilton 2000). The lithics recovered from within these sites comprise the local source of lithic raw material, the Precambrian Gunflint Formation.

The Gunflint Formation, which is the main source of the lithic material in the Thunder Bay area represents an almost continuous outcrop of Precambrian sedimentary rock. It extends from just west of Gunflint Lake on the Minnesota and Ontario Border for about 180km north east, at which point, exposed outcrops appear as isolated pockets for an additional 120km west of Schreiber, Ontario where the formation ends (Awramik and Barghoorn 1977; Goodwin 1956; Pufahl and Fralick 2000; Fralick, et al. 2002; Jirsa et al. 2011). Simplifying the lithostratigraphy of the formation, it can be divided into three members, a basal conglomerate, a lower member which is made of siliceous grainstones (taconite) capped by a layer of fossilized stromatolites and an upper member which is made up predominantly of alternating layers of iron rich "cherty" grainstones and shale/slate (Pufahl 1994, Pufahl and Fralick 2000).

1.2 Descriptions of Raw Material Types

Gunflint silica has been described by Bakken (2011), McLeod (1978) and Romano and Johnson (1990). They agree that Gunflint silica is highly variable in terms of homogeneity, workability and quality from poor to excellent. Many authors have commented on its translucent chalcedonic matrix and "pepper like inclusions", observed when samples are held to the light (Romano 1991, Wendt 2003). Romano (1991), also noted that some examples have very few inclusions, or contain black bands observable when held to the light, however these are less common. The lustre of gunflint silica ranges from waxy to glossy. Some descriptions suggest this material blends into jasper taconite and other Gunflint materials (Bakken 2011), however an alternative way to categorize these materials would be to place Gunflint silica and taconites into the same category as the difference between the two varieties is only a reflection of the spaces between granules.

Both jasper taconite and taconite were described by Bakken (2011) during his work categorizing the raw materials observed in Minnesota. He notes that this material is almost always cranberry red, although rare examples of bluish-black, and dark green can also occur (Bakken 2011). On the Canadian side blueish-black and dark green are very abundant and co-occur with the cranberry red varieties within outcrops (Figure 6) however a white variety has also been observed. On the thin edges of flaked taconite, the matrix is transparent for both red and dark blue varieties. However, small rounded inclusions can be observed when held to the light. By the geologic definition, this material is referred to as a 'grainstone', which is a particular type of sedimentary rock that is unique, as it is made up of grains of sand cemented together in a matrix of silica (Goodwin 1956; Bakken 2011). Bakken (2011) indicates this material has a tendency to grade into sections, which resemble Gunflint silica.

Kakabeka chert can be described as banded chert with alternating bands of carbonate and cherty materials (Lindenberg & Rapp 2000). The band colouring varies from a black, dark blue, grey, or brown bands to lighter ones which can be yellowish-brown, or blue-grey (Lindenberg & Rapp 2000).

1.3 Previous Studies Related to Lithic Analysis in the Study Region

Much of the previous research that has been conducted with respect to lithics in the local region, has focused predominantly on the general morphology of formal tools and to a less extent on the chemical analysis of the raw materials (Bennett 2015, Markham 2012, Norris 2012, Wendt 2003, Borradaile et al. 1993, Ross 1979). This study aims to address the selective factors that ancient people possibly faced when acquiring the raw materials they used when manufacturing stone tools. Firstly, this study breaks selective factors into three categories; availability, culturally influenced selective choices and raw material physical characteristics.

1.4 Availability

Accessibility and material abundance falls into this category; the landscape is an important characteristic, which should be considered when examining material of this nature. The logistical concerns that one has to consider when quarrying raw materials, firstly, how easy is it to get to a quarry location, and secondly, when one arrives how hard is it to remove raw stone from the quarry (or secondary deposit) location. Also important is the abundance of the desired material on the Landscape. The desired raw materials, which are exploited from the Gunflint Formation, are quarried almost exclusively from the upper member of the Gunflint Formation by easily prying the cherty layers from within the weak shale layers (Julig 1984). In terms of location and abundance, primary quarry sites are situated near shoreline locations and are thus equally accessible. The taconites and Gunflint silica material are co-occurring within the upper member of the Gunflint Formation, however, Gunflint silica tends to appear sporadically within a quarry face and is less abundant. Kakabeka chert is the only material that occurs in the lower member of the Gunflint Formation and appears with less frequency at archaeological sites.

Figure 6 *Tabular block broken from the outcropping at the Shuniah Mine Quarry*

Figure *7 Another example of Gunflint Formation reflecting a darker variety of Taconite.*

1.5 Culturally Influenced Selective Pressures

The visual appearance (colour, lustre, translucency, etc.) of a raw material can be argued in certain cases as a determining factor during the selection process at the quarry (Berleant 2007). Lithic analysis and interpretation in archaeology is often conducted from an economic perspective (Markham 2015, Hamilton 2000). However, characterising lithic material and interpreting it from not only the economic but also a cultural perspective may provide an unsuspecting insight into past people and their raw material selection strategies.

Notably, this is a difficult undertaking when one is investigating debitage; as the practice of flint-knapping is a process of reduction, whereby the ancient manufacturer is removing raw material (Dibble 1987). Thus, at least in the sense of manufacturing debitage from a core or flake blank the process reflects the removal of undesirable material. When examining the macroscopic characteristics of a raw material with a high degree of variability (Figure 6 and 7) the aforementioned duality makes it difficult to determine culturally influenced selective pressures. Additionally, the time consuming nature of examining each flake with the sheer number of lithic flakes in any given debitage scatters makes the process extremely time consuming, and from a cultural resource management perspective fiscally undesirable.

Another complication, which is more related to archaeology in the boreal forest is that, it is difficult to separate temporally differentiated strata due to the extremely slow soil development and well defined temporal changes are required when cultural values can change quickly over time (Hamilton 2000). Therefore, the alternative may be to examine more refined formal tools, from a single occupation event, to determine these cultural selective pressures.

1.6 Raw Material Physical Characteristics

There are many factors, which determine how well a lithic raw material flakes; however, the ways that contemporary flintkappers articulate these attributes are often subjective. Moreover, contemporary experimental archaeologists provide the only means of understanding the unique characteristics of a raw material, which may have been a relevant consideration of ancient manufacturer. Analytical methods continue to be developed and applied to the analysis of lithic material but it is difficult to balance both the need for a scientifically controlled environment and a realistic representation of the manufacturing process of the ancient art of flintknapping. Careful examination of both approaches whether, heavily controlled or more intuitive will lead to a more holistic understanding of selection pressures in respect to the physical properties of lithic materials.

The challenges of investigating the physical properties are similar to those faced when investigating the culturally influenced selective pressures. Debitage is abundant, the process is time consuming and investigating changes though time are difficult where there is little soil development.

1.7 Methods

The methodological approach was developed to examine the macroscopic characteristics, of seven artefacts from a local lithic cache and compare them to two local quarry sites the Shuniah and Cummins sites. The visual characteristics of colour, lustre and translucency are part of the standard practice of any study related to lithic raw material studies (Crandle 2005, Morrow 1994) while the determination the physical "flaking" quality was made using a novel method that has not been tested on reference samples of known archaeological quarries. The results of each of the methods used for visual characterization, which could be an indication of culturally influenced selection, were statistically compared to the physical flaking characteristics of the material to see if there was any relationship between any of the visual characteristics and their flaking performance. Heat treatment of lithic materials was not applied to any of the tested materials, as it was not likely part of the manufacturing processes involving Gunflint Formation materials in the area during the Paleoindian period (Borradaile et at. 1993, Romano, 1991)

1.7.1 Digitally aided Colour Identification

The identification of colour on lithic materials was performed in a similar fashion to that used by Stanco and team (2012) during their approach to analyse the colours of pottery artefacts. Modifications were implemented to capture the complexity analysing the multiple colours, which often appear in heterogeneous lithic materials. The Macbeth colour calibration chart, used by Stanco et al (2012), has been replaced with an X-rite colour calibration card. The *X-rite Colorchecker Passport Photo* calibration card was used because of the associated software that came with the calibration system that could be incorporated into Adobe Photoshop. The calibration card used in experiments must remain consistent for comparisons between samples in and across studies. The *X-rite Colorchecker Passport Photo* software generates an RGB colour calibration profile that is used as a comparison between the known colour values on the colour chips in the colour passport and what the camera has captured in a photograph. The data taken by the camera is then used to generate a colour profile, which can be applied to digital negatives to ensure matching real world and virtual colour representation.

These digital negative photographs of lithic materials were then imported into Adobe Photoshop where the *X-rite Colorchecker Passport Photo* software generated colour profile was applied, calibrating the photographs to match the real world representation of the material. Following this calibration the background of the photograph and any cataloguing labels present on the lithic surface were digitally removed. This was done to eliminate any unwanted white/grey shades and labelling ink, which would contaminate the results of the colour analysis. Following this manipulation of the lithic image, it was imported into an open source program, which is based in *Matlab*, called *Colour Inspector 3D*, where the data contained in the Look-up-Table (LUT) could be graphed and expressed in an Excel spread sheet.

The LUT is the 8 bit data of each pixel in an image in RGB colour. The white background of each image was represented by the pixels that had the RGB colour of Red: 255, Green: 255 and Blue: 255. These pure white pixels were also discarded from the analysis, as background. The percent of the remaining pixels were then ranked and the top ten pixel colours were selected for the documentation of colour. Selected pixels were converted into the Munsell system from the standard Red Green Blue (sRGB) system providing multiple means of articulating colours of each lithic material to allow comparison to artefacts analysed using each of the various colour measurement schemes. Centore (2013) has indicated that the sRGB system is compatible with the Munsell system only requiring a conversion via another colour space created by the International Commission on Illumination (CIE) in 1931 known more simply as CIE. He haskindly provided conversion tables in his research (Centore 2013), which were used to convert the sRGB colours to the Munsell. These conversions were provided in order for the data to be comparable to other preceding lithic raw material classification systems.

1.7.2 Translucency

Translucency was determined using the method outlined by Ahler (1983) which has been used by other researchers to calculate translucency (Luteke 1992, Morrow 1994, Crandle 2005). In this method a sample is held at a known distance from a 70-100w light bulb (usually 30cm), a digital calliper is then used to measure the point of thickness on the sample where it becomes opaque. For this research a high-powered daylight 100w LED bulb was chosen. The measurements were taken 5 times in multiple locations on the sample using the calliper to produce an average translucency measurement for each lithic sample.

1.7.3 Lustre Intensity Identification

For the quantitative assessment of lustre a GM-26 glossmeter, which measures the amount of specular reflection of the surface of a sample at an angle of 60° was used. Glossmeters typically have measurement angles of 20°, 60°, and 85°. The more acute angles are typically used on duller materials while materials with higher lustre are measured with an angle of 90°. A glossmeter capable of measuring lustre at 60° was chosen for this research because it falls within the midpoint of the available measurement angles.

Each sample was placed under the glossmeter. These samples were freshly flaked material and not cut material, as cutting the lithic material creates scratches that would affect general lustre. After each sample the glossmeter was recalibrated using the provided calibration plate. The area that was illuminated was approximately 1cm in diameter, which was sufficient for covering the majority of the freshly flaked surface of the material. A fresh flake of the sample material, with a large and relatively flat fresh surface, was selected for this analysis. The sampling measurements were taken from ten locations on the surface of the material and averaged to give an indication of the average gloss of the sample.

1.7.4 Tenacity

A large core of material was collected for each sample from the field. This large field-collected core sample was cut into similar size rectangular blocks with the approximate dimensions of 10cm wide by 30mm long and 10cm thick using a diamond blade lapidary saw. Cutting of the material was important for the removal of any pre-existing flaws, so an assessment of the tenacity of material without flaws could be made.

The current study follows the methodology presented by Dibble and Rezek (2009) in terms of using a load cell, which is a device, used to measure the amounts of force. In this study the load cell served as a means for identifying the amount of force required to remove a flake from a core. As this was a preliminary assessment of the methodology the material used to test the utility of this method was glass. Dibble and Rezek (2009) directed their focus at better understanding the characteristics of flake formation. The application of this methodology to testing the characteristics of raw materials, other than glass, proved to be a bit more complex than anticipated.

Firstly, the shape of the glass core used was hard to replicate while cutting raw lithic material. The difficulty of shaping samples was most apparent with varieties that contained many natural flaws. It would have proven time consuming to grind materials down into shape rather than cutting them, which in turn would have severely limited the sample size that could be investigated. The starting platform angle used by Dribble and Rezek's (2009) was 65°. In the application of their method to this research, the angle was changed to 90°. The cubed samples were placed in a drill-press-vise in-between a piece of bison hide. The bison hide was used to replicate as closely as possible the process to which ancient flintkappers would hold the samples. The angle of 90° was achieved by manipulating the sample in relation to the load cell, leaving a section of the sample over hanging outside the sides of the vise and by leaving a space between the bottom of the vise and the sample. The back edges of the sample acted like a hinge when the tip of the load cell was pressed into the sample, this allowed an action, which mimicked the movement of a flintknappers wrist.

Striving for a controlled but somewhat more accurate replication of the process of flintknapping, a specially manufactured copper bit was used to replicate as close as possible the tips used during the process of pressure flaking. Although bone/horn/antler could also have been used these materials are difficult to machine and much more difficult to control uniformity. However, because there is no evidence copper was used in the flintknapping process during the Paleoindian period its implementation in this study simply serves as a closer proxy to a piece of bone, horn or antler. Copper tips are a good proxy because the relatively soft material tends to "bite" onto the platform much better than the harder steal tips, which often slide off the platform of the sample. The edge of the sample holding a 90° angle was used as the platform. The tip of the force gauge was placed at 1mm from this 90° edge of the sample in an effort to control the platform depth and to simulate uniformity in the flaking process.

The manufactured copper tip was then slowly compressed into the sample until a flake was removed. A push-pull force gauge then reads the maximum amount of force that was required at that point to remove the flake. The analytical process was replicated five more times so that an average amount of force required to remove a flake could be calculated. In addition, the minimum amount of force required to remove the flake was also recorded.

1.8 Data Results

The translucency was measured on all of the samples in this study (Table 1). The translucency ranged from 0.00 to 15.02. The measurement of 0.00 indicates a sample that is opaque. All three locations have great diversity with measurements of translucency with Shuniah showing the greatest range followed by Cummins and the artefacts from the Crane site. The Shuniah site has the highest measurement of 15.02 while all three sites have samples measuring 0.00 (opaque).

The results of the glossmeter are recorded by the average gloss per sample (Table 1). These measurements ranged from 0.26 to 2.00. The highest measurement recorded was from sample ON-CS-06 from the Cummins site while the lowest is from the Shuniah site. The colour of each of the samples studied are represented in Munsell colours (Table 1). The hue values range from a Green and Green Yellow to a Yellow and Yellow Red colour.

The minimum force measure in Newton (N) is determined for each sample separated by site (Table 2). The minimum force required for the flaking of each sample ranges from 50N to 325N. The largest range of forces required were found in the material from the Shuniah site. The Cummins site had the smallest range from 60N to 225N. While the artefacts from the Crane site were not analysed due to the destructive nature of these tests.

Table 2 *The results of the macroscopic & experimental flaking of the samples separated by site*

Sample	Site	Translucency (mm)	Average Gloss (gu)	Munsell Colour	Minimum Force (N)
ON-SM-56	Shuniah	2.50	0.49	5G 7/2	60
ON-SM-53	Shuniah	1.03	0.55	5G 2/2	100
ON-SM-51	Shuniah	1.18	0.39	10G 6/2	50
ON-SM-50	Shuniah	0.89	0.55	5G 3/2	100
ON-SM-49	Shuniah	1.30	0.47	5G 3/2	125
ON-SM-48	Shuniah	0.66	0.60	2.5Y 3/2	140
ON-SM-45	Shuniah	5.79	0.76	5G 3/2	50
ON-SM-43	Shuniah	1.30	0.57	2.5Y 2/2	55
ON-SM-40	Shuniah	0.54	0.40	7.5GY 4/2	90
ON-SM-39	Shuniah	2.25	0.47	7.5GY 3/2	100
ON-SM-37	Shuniah	1.89	0.55	7.5GY 3/2	125
ON-SM-36	Shuniah	2.31	0.93	7.5GY 4/2	200
ON-SM-35	Shuniah	3.02	0.34	7.5GY 3/2	175
ON-SM-34	Shuniah	2.43	0.34	5G 3/2	225
ON-SM-32	Shuniah	4.19	1.09	5G 2/2	125
ON-SM-30	Shuniah	1.62	0.44	5G 2/2	125
ON-SM-29	Shuniah	1.47	0.38	5G 2/2	90
ON-SM-28	Shuniah	1.02	0.47	5G 2/2	75
ON-SM-27	Shuniah	2.47	0.34	7.5GY 3/2	125
ON-SM-26	Shuniah	0.00	0.47	5Y 5/2	75
ON-SM-25	Shuniah	1.17	0.44	5G 3/2	175
ON-SM-24	Shuniah	1.67	0.69	7.5GY 6/2	125
ON-SM-23	Shuniah	1.65	0.69	7.5G 8/2	275
ON-SM-22	Shuniah	4.40	0.63	2.5Y 4/2	190
ON-SM-21	Shuniah	1.29	1.17	5G 2/2	135
ON-SM-20	Shuniah	1.34	0.32	2.5Y 4/2	100
ON-SM-19	Shuniah	1.78	0.91	7.5Y 7/2	75
ON-SM-17	Shuniah	0.71	0.44	7.5GY 5/2	75
ON-SM-15	Shuniah	1.44	0.39	7.5G 4/2	225
ON-SM-14	Shuniah	0.82	0.26	7.5G 4/2	325
ON-SM-08	Shuniah	15.02	0.78	5Y 3/2	75
ON-SM-05	Shuniah	6.88	0.66	5GY 5/2	125
ON-SM-03	Shuniah	8.30	1.32	5G 2/2	75
ON-CS-12	Cummins	0.00	1.06	5YR 2/2	75

Sample	Site	Translucency (mm)	Average Gloss (gu)	Munsell Colour	Minimum Force (N)
ON-CS-10	Cummins	1.31	1.48	5GY 2/2	100
ON-CS-09	Cummins	2.12	0.62	5G 2/2	225
ON-CS-08	Cummins	0.83	0.77	5YR 2/2	60
ON-CS-06	Cummins	1.12	2.00	5YR 2/2	60
ON-CS-05	Cummins	1.19	1.36	7.5G 4/2	100
ON-CS-04	Cummins	1.11	1.66	5G 2/2	125
ON-CS-03	Cummins	1.11	1.75	7.5GY 3/2	150
ON-CS-02	Cummins	1.06	0.66	5G 2/2	100
ON-CS-01	Cummins	1.04	1.12	5YR 3/2	100
Biface-BB1	Crane	1.50	0.88	5GY 2/2	N/A
Biface-51	Crane	0.00	0.78	5YR 3/2	N/A
Biface-44	Crane	0.84	1.24	5Y 3/2	N/A
Biface-42	Crane	0.75	0.58	7.5GY 3/2	N/A
Biface-31	Crane	1.16	0.55	5YR 3/2	N/A
Biface-12	Crane	0.90	0.53	7.5GY 2/2	N/A
Biface-Sur1	Crane	0.79	0.54	5G 3/2	N/A

A comparison between the hue and the average minimum flaking force of the samples was made (Table 3), where the bifaces from the Crane site were added into the sample grouping based on their identified hue. The majority of the bifaces (n=5) fell into colour hue grouping which had an average minimum flaking of under 130N.

Table 3 *The categories of Munsell Hue and the average minimum flaking measurements*

Samples	Munsell Hue	Average Minimum Flaking
ON-SM-36 ON-SM-48 ON-SM-21 ON-SM-24 ON-SM-22 Biface-BB1 Biface-51 ON-SM-23 ON-SM-25 ON-SM-32 ON-CS-09	7.5GY	129.44N
ON-SM-37 ON-SM-49 ON-SM-50 ON-CS-06	7.5G	231.25N
ON-CS-12 ON-CS-01 ON-CS-04 ON-CS-05 Biface-12 Biface-31	5YR	73.75N
ON-SM-34 ON-SM-51 Biface-44	5Y	75N
ON-SM-53 ON-CS-51 Biface-42	5GY	112.5N
ON-SM-03 ON-SM-14 ON-SM-15 ON-SM-19 ON-SM-26 ON-SM-35 Biface-Sur1 ON-SM-05 ON-SM-27 ON-SM-28 ON-SM-29 ON-SM-30 ON-SM-40 ON-SM-56 ON-CS-03 ON-CS-08 ON-CS-10	5G	197.55N
ON-SM-39 ON-SM-43 ON-SM-17 ON-SM-20	2.5Y	190.18N

The comparison of average translucency of a sample compared to the minimum amount of force required to remove a flake per sample was assessed (Figure 8) to determine if there wasa correlation. Likewise, the average gloss of a sample compared to the minimum amount of force required to remove a flake per sample were compared (Figure 9). Both of these comparisons showed no significant statistical relationship between these macroscopic characteristics and the flaking properties of samples. The average translucency compared to the average minimum force required to remove a flake had a Pearson's R statistic value of -0.273 (Figure 8). The average gloss measurement compared to the minimum amount of force required to remove a flake had a Pearson's R statistic value of -0.246 (Figure 9).

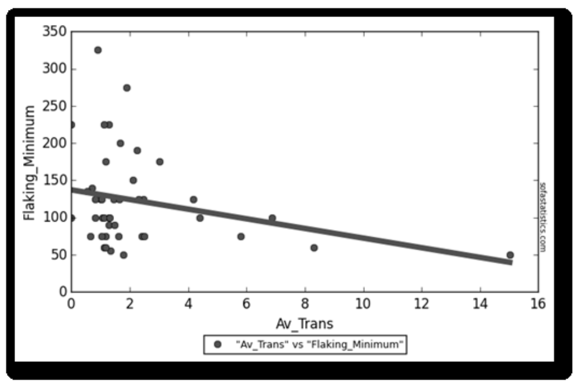

Figure 8. *A bivariate statistical analysis of the average translucency of a sample compared to the minimum amount of force required to remove a flake per sample*

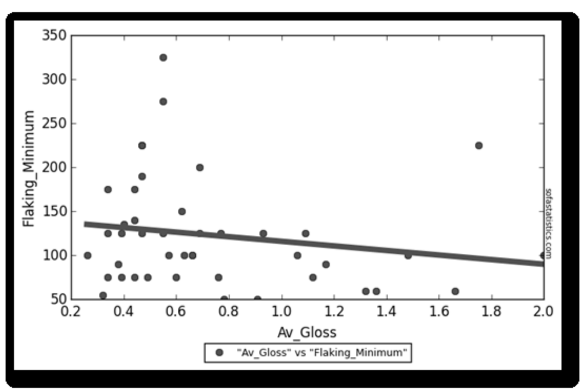

Figure 9. *A bivariate statistical analysis of the average gloss of a sample compared to the minimum amount of force required to remove a flake per sample*

1.9 Interpretations of the Data

In the collection of samples analysed in this study, there is a sample bias related to the samples collected from the Shuniah Quarry site. There was a much higher degree of variation in the visual appearance of the reference lithic materials collected. However, this is due to the initial sampling strategy that was to collect as much diversity as possible to assess the full range from this site. This bias was most apparent when examining samples from the multiple sites and particularly when making comparisons between quarry sites. When comparing samples just from the Shuniah Quarry site and the rest of the formation, the bias is not evident.

1.9.1 Translucency vs. Flaking Qualities

When investigating the relationship between translucency and flaking qualities there was no statistically significant association found. There are a few conceivable reasons for the lack of a correlation. Firstly, taconite is a siliceous grainstone, which implies that it is made up of tiny granules cemented in a silicate matrix. These grains distributed randomly often overlap one another in layers and subsequently block out the light passing through the samples as the material becomes thicker. Although, the cement matrix surrounding the granules remains clear.

The related material from the Gunflint Formation, Gunflint silica, has been historically categorized as a separate raw material (Romano 1991). This is due to the higher translucency that has been reported in the literature for this material (Romano 1991). The translucency of Gunflint silica is caused by the presence of fewer and wider dispersion of granules within the siliceous matrix. With respect to flaking qualities the Gunflint Silica been described in the literature as a more brittle material (Romano 1991). In this research, due to sample availability, only samples ON-SM-03, ON-SM-32 and ON-SM-45 represent the Gunflint silica. The translucency of the

Gunflint silica samples were above average when compared to the samples of taconite from the formation. Due to significant sample bias any possible comparisons which could be made regarding the flaking qualities between these two related materials would be difficult.

Therefore, in this research, translucency did not have any statically relevant relationship. This may suggest that translucency did not impact the selection of raw material. This argument implies that in the case of taconite, translucency was not an important feature for the selection of this material at the quarry sites by the ancient artisan(s) and can be extended to those who manufactured the bifaces at the Crane site.

There are a few caveats with this implication, which should be considered. Firstly, the way the raw material has geologically formed. As, previously mentioned the material is made from layers of cemented granules. These overlapping layers often block out the transmission of light through and within the material with increasing thickness of the material. Silica content which has an impact on the formation and propagation of flakes, cannot accurately be assessed with the visual examination of translucency, however mineralogical thin-sectioning gives better indication of what is occurring when light passes through and within the material.

The observed hematite/magnetite granules are opaque (a common diagnostic feature of the highly ferrous minerals in thin sections) and do not transmit light. The jasper (which is a form of chert) granules are semi-translucent and show the characteristic appearance of chert under crossed polarized light. The matrix that cements the granules together is a chalcedony and is highly translucent. The lack of translucency, in this material, does not mean that this characteristic would not be an important characteristic in other raw materials or geographical regions but in this study, at this location, it is less important.

1.9.2 Lustre vs. Flaking Qualities

The relationship between lustre and flaking qualities also did not show a statistically significant correlation. The likely reason for this, is that both the metallic minerals (hematite/magnetite) and the silicate minerals (jasper/chalcedony) exhibit a high degree of lustre. However, minerals either fell into two different lustre types one is metallic and the other is vitreous. Mineral granules are not always dispersed evenly and do not reflect light in a uniform fashion. In the case of the Gunflint Formation the use of a glossmeter and measurement of lustre was not as effective as it has been at other formations. However, the glossmeter did provide useful information regarding the lithic material from the archaeological record. The results from the glossmeter indicates that post-depositional factors have affected the lustre of the bifaces from the Crane site. The average lustre of the artefacts from the Crane site was much lower than the lustre observed in the reference samples. In conclusion, the usefulness of the glossmeter and measure of gloss as an indication of lustre needs to be investigated further, in more archaeological collections, with more rock types, and in more studies, using a broader sample set. However, it does provide some promising preliminary results.

1.9.3 Colour vs. Flaking Qualities

Colour and flaking qualities did show a statistical relationship in this study. On visual inspection of the collection of bifaces from the Crane site, the majority had a considerable amount of red (jasper) granules present, with the exception of one biface. This one biface was made from Kakabeka chert and was the only biface within the entire Crane site, which was made from this raw material. From the seven bifaces selected from the Crane Site, six out of the seven samples were close to the acquired colour values of the raw material with a minimum flaking force under 150N. The rusty cortex of some raw materials, however, often pushed some samples into a colour hue closer to the colour of the cortex and not in the range of the siliceous raw material. In the Gunflint Formation, the rusty cortex of the raw materials tends to be uniform across all lithic raw material types. Irrespective of this particular observation, the colour analysis did show some promise, specifically that the colour red did have a correlation with how easy the material breaks. The samples with red colour 5YR on average required the least amount of force to break (thus flake) when compared to the other colours. The red 5Y colour was the next easiest lithic raw material to break. Just under half of the bifaces fit into the 5YR or the 5Y colour categories. Upon visual non-computer aided inspection, the number of bifaces, which exhibited a high jasper (red) content (n=5) could also be made from materials, which flake at lower pressure. Therefore the dominance of the colour red in the bifaces from the Crane Cache and other sites in the area is more likely a reflection of the physical properties of the raw material and less so a reflection of the appeal of the colour itself. However this does not refute the possibility that the colour red was of some cultural value, this is still a possibility.

1.10 Conclusion

This study, contributes to our understanding of the strategies that may have been used in the past for lithic raw material acquisition. It has helped to develop a scientific baseline of characteristics, of the local lithology of the Gunflint Formation. One of the aims of this study was to address the question, to what degree do cultural influences or physical properties affect the selection the lithic raw material by ancient people of Northwestern Ontario. In this study, novel methods were employed to assess characteristics of lithic material that are significantly different than the original intended purpose of those techniques. The application of these techniques however have revealed their potential use in addressing very different research questions which require further investigation.

Acknowledgements

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Chapter 4

Combining Traditional and New Methods for the Description and Sourcing of Raw Lithic Materials from the Gunflint Formation, Thunder Bay ON.

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Abstract:

The sourcing of lithic materials and stone tools made from chert is notoriously difficult. However researchers are developing and improving methods and techniques to address the question of where in a geographical area is a raw material for lithic artefacts collected. There has been some promise refining this to a particular formation but achieving outcrop specific locations has been challenging. With respect to the local study area of Thunder Bay, Ontario, we know that the Gunflint Formation is the source for the majority of lithic materials, however covering a length of 170km, knowing where specific quarry locations are, would help better understand stone tool manufacturing in the region. This research aims at combining traditional methods of sourcing chert using visual characteristics with new, physical characteristics, along with chemical methods in order to determine the most likely source for a selection of bifaces from a local cache site.

Keywords: Raman Spectroscopy, PXRF, FTIR, pressure flaking, lithics; quarry sites; stone tools, macroscopic characteristics, biface cache.

1.1 Introduction

Lithic sourcing has been an important approach to investigating questions relating to past resource exploitation, trade routes and migratory patterns. Chemical approaches for sourcing lithic material has focused primarily on igneous raw materials, while approaches to sourcing sedimentary raw materials are limited (Moreau 2016). This study focuses on the application of three non-destructive spectroscopic techniques for chemical lithic sourcing and the assessment of each method in determining the source of a lithic artifact down to an outcrop level which when applied may complement one another. Comparisons of these approaches to traditional methods, specifically using the physical characteristics of a raw material, will also be examined. How these methods may complement each other will be examined to determine how specific and accurate lithic sourcing of sedimentary material can be achieved. Three collections will be examined, a cache of biface stone tools and two known quarry sites in Northwestern Ontario, Canada that are both part of the Gunflint Formation. The cache of biface stone tools are from the Crane site in Northwestern Ontario. The two quarry sites, which have been archaeologically investigated, are the Cummins Quarry (Dawson 1983) site and the lesser known Shuniah Quarry site (Hinshelwood 1993) which are both possible sources or closely related to the source material for the bifaces found in the Crane site cache (Ross 2011).

The most traditional approach to lithic sourcing involves examining the macroscopic features of a material and examining where similar looking materials appear within a source location. The contemporary approach is to combine this method with chemical analysis to determine the similarities with the elemental chemistry of the material. The more similar lithic material is to the source location both chemically and macroscopically the higher the probability that the two are indeed from the same location. There are limitations to lithic sourcing such as the presence of secondary deposits of lithic materials (sources not from a stationary quarry location) which often were used for the manufacture of stone tools by ancient peoples.

Although past lithic sourcing studies have elected to use methods such as neutron activation analysis (NAA) and proton induced X-rays (PIXE) and gamma rays (PIGME) achieving some success (Summerhayes et al. 1998, Shackley 1998, White & Harris 1997, Julig et al. 1992). Three other non-destructive spectroscopic methods were employed in this study to characterise the chemical make-up of the raw materials found at the two quarry locations. Portable X-ray Reflectance Spectroscopy (P-XRF) was used to identify the elemental composition of the lithic material. Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR) was used to characterise the chemical composition based on bond energy. Raman Spectroscopy was used to characterise the chemical composition based on bond excitation energy. This approach has been previously documented by Olivares and team (2013) and showed that there is some benefits to this combined approach as it allows for a more holistic analysis of the chemical makeup of raw lithic material.

1.2 Samples

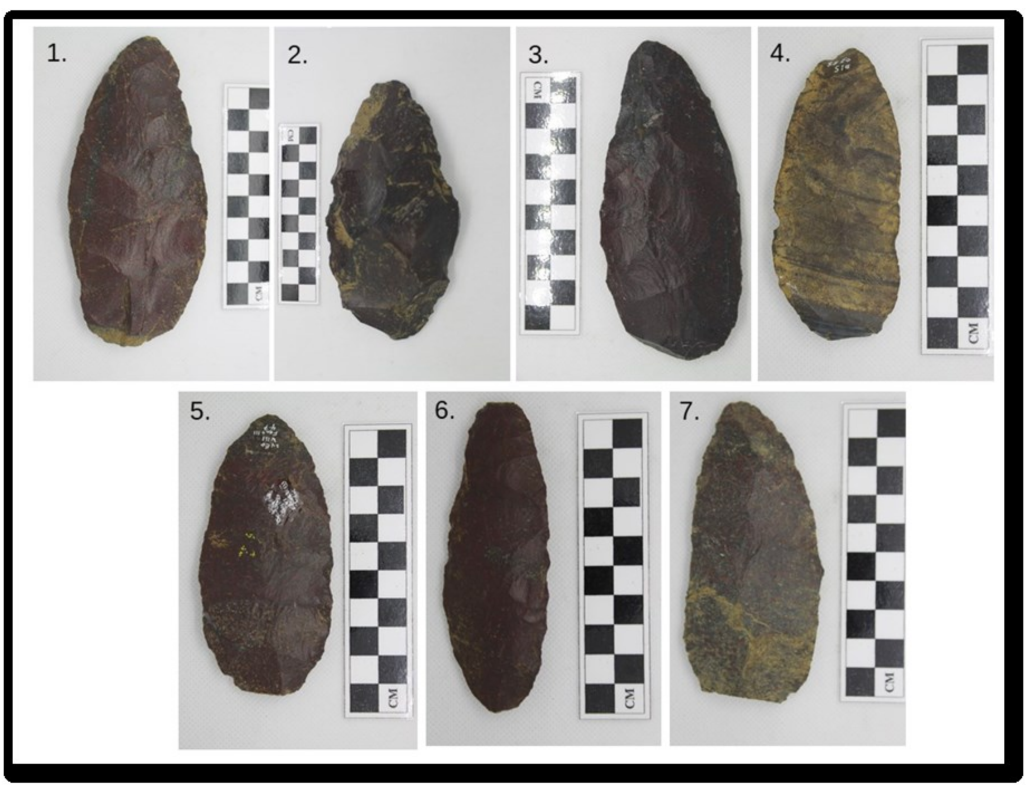

Figure 10. *Biface-41 (1); Biface-Sur1(2);Biface-BB1(3); Biface-51 (4); Biface-44 (5); Biface-12 (6); Biface-31(7)*

Seven bifaces from the Crane Site were selected for this study, from a cache of 153 bifaces. The samples were made entirely of Gunflint Formation material. The bifaces were in a late stage of manufacture close to their intented final form. The tips were still blunt and the edges while thin were not optimized for utilisation. The macroscopic appearance of the raw material cache was uniform with only one biface being made from a less common raw material from the Gunflint Formation called Kakabeka chert. The Crane site was excavated in the late 1980's by Government of Ontario Archaeologists William (Bill) Ross and David Arthurs after it was found in a potato garden by local resident Mr. Crane (Ross 2011). The methodology of excavation was conducted at 3cm interval levels with trowels. The archaeological material was deposited in a sandy subsoil which was under an organic topsoil specifically at the transition between the two layers. The sites location which was far from any source of water and local raw lithic material in conjunction with the finding of post holes suggests to the excavation team that the site is a winter encampment (Ross 2011).

The Cummins site is a quarry location along with a cremation burial site located within the city limits of Thunder Bay, Ontario. The Cummins site burial has been dated to 8090 to 8870 ± 390 BP by radiocarbon dating however other areas of the site could be perhaps much older (Ross, per com. 2018) (Dawson 1983). The site is perhaps the most researched quarry location on the northwestern shores of Lake Superior. The quarried material is jasper taconite, and this was also the material quarried out of the Shuniah site and represented the material that the bifaces from the Crane site were manufacture (Steinbring 1976, Dawson 1983, Julig 1984, Julig 1990). The Cummins site is significant because it provides a temporal context to quarrying activities in the Thunder Bay area during the Paleoindian period.

The Shuniah site (Black Sheep site) also known as DcJh-40 was excavated by Andrew Hinshelwood and team in the early 1990's and then revisited by Christopher Hamilton in fall of 2016. The site is located along a geological slip strike fault which forms a small valley which is shown in geological maps of the area (Pye and Fenwick 1963). Flakes and early stage bifaces were found along the banks of this valley at the point where the upper member of the Gunflint Formation outcrops (per com. C. Hamilton 2016). The distribution of artifacts being found specifically along the unlevelled banks of the sides of the valley along with the absence of more refined stone artifacts indicates that the site is another quarry location.

For this study seven bifaces were selected to be compared to 10 raw material samples from the Cummins Quarry and 33 raw material samples from the Shuniah Quarry. More samples were examined from the Shuniah Quarry because the site location is also near the contact between the upper and lower members of the Gunflint Formation, therefore there were more varieties of macroscopically differing raw materials to examine. While at the Cummins site, material varieties were represented entirely from the upper member of the Gunflint Formation.

Figure 11. *The Shuniah Quarry area where reference samples were collected*

1.3 Methods

1.3.1 Microscopic Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy

The micro-ATR-FTIR is capable of analyzing the surface of the material non-destructively. Spectra were generated on a BRUKER TENSOR 37 (FTIR) spectrometer with an InGaAs Detector 12.8-5.8K and CAF2 10- 1.650cm^{-1} beam splitter. This was coupled with a Bruker Hyperion 2000-IR Microscope with 4X, 15X and 36X objectives and polariser. The micro-ATR-FTIR also used an ATR-Ge objective (20X) for the IR microscope for diffuse reflectance analysis. The Spectrum IR software package was used for the collection of data, acquired between 4000 and 400cm^{-1} with 32 scan time and set at a spectral resolution of 5cm^{-1}. The samples were analyzed in triplicate. OPUS computer software was used to analyze the spectrum from 4000-500 cm^{-1}.

1.3.2 Microscopic Raman Spectroscopy

Raman Spectroscopy can be used to analyse materials non-destructively. It was used in this study to characterise material source locations within a formation. A confocal micro-Raman Spectrometer consisting of a Nikon E400 upright microscope coupled to a Chromex 250IS optical spectrograph with a cooled CCD camera as the detector. The laser line chosen for the excitation was a 5mw Argon Ion Laser at 514.52nm. The laser input for the microscope was directed through the fluorescence lamp providing unpolarised light that required averaging to address any directional effects. A 2mins exposure time using the flowing run condition was set which resulted in a spectral bandwidth of 1300 wavenumbers. Samples were placed on a calcium fluoride substrate to eliminate any contamination in the spectra from silicate bonds produced by using glass microscope slides. The sampling area was taken at 100x magnification, which resulted in a sampling area of 1-10nm^2.

1.3.3 Portable X-ray Fluorescence Spectroscopy

A Portable X-ray Fluorescence Spectroscopy (P-XRF) was used to analyse the elemental composition of the samples. Samples were tested using a Bruker P-XRF system at 40eV with 15µAmp and a 60sec exposure time. P-XRF is also a non-destructive technique and is more commonly used in geology, archaeology and historical conservation fields (Olivares et al. 2013).

1.3.4 Macroscopic Identification Methodologies

Traditional techniques characterising lithic materials based on their physical properties were also employed. Physical properties such as luster, translucency, colour, tenacity, petrographic thin-sections, and specific gravity were examined. This study employs improved quantitative methods that have been applied to the examination of these physical properties (Dibble and Rezek 2009; Crandell 2005; Stanco et al. 2012; Morrow 1994). The parameters for these improved quantitative methods have been presented elsewhere. These improved traditional approaches were compared to the spectrographic approaches.

1.4 Results

1.4.1 Microscopic Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy

The Micro-ATR-FTIR did not produce very useful results for the differentiation between different raw material outcrops. All of the samples from the Cummins Quarry site were identical (Figure 12) likewise were the samples from the Shuniah Quarry site (Figure 13). However, on comparison between the two quarry sites there is also no difference between the spectra.

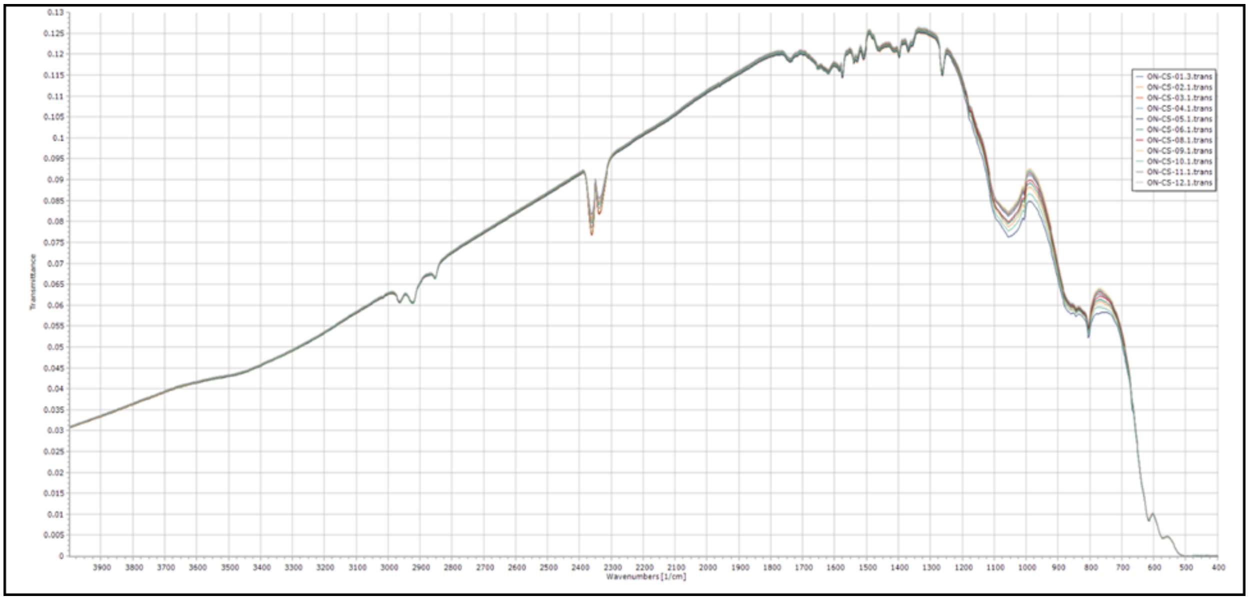

Figure 12. *The FTIR spectra of the raw material samples from the Cummins Quarry site*

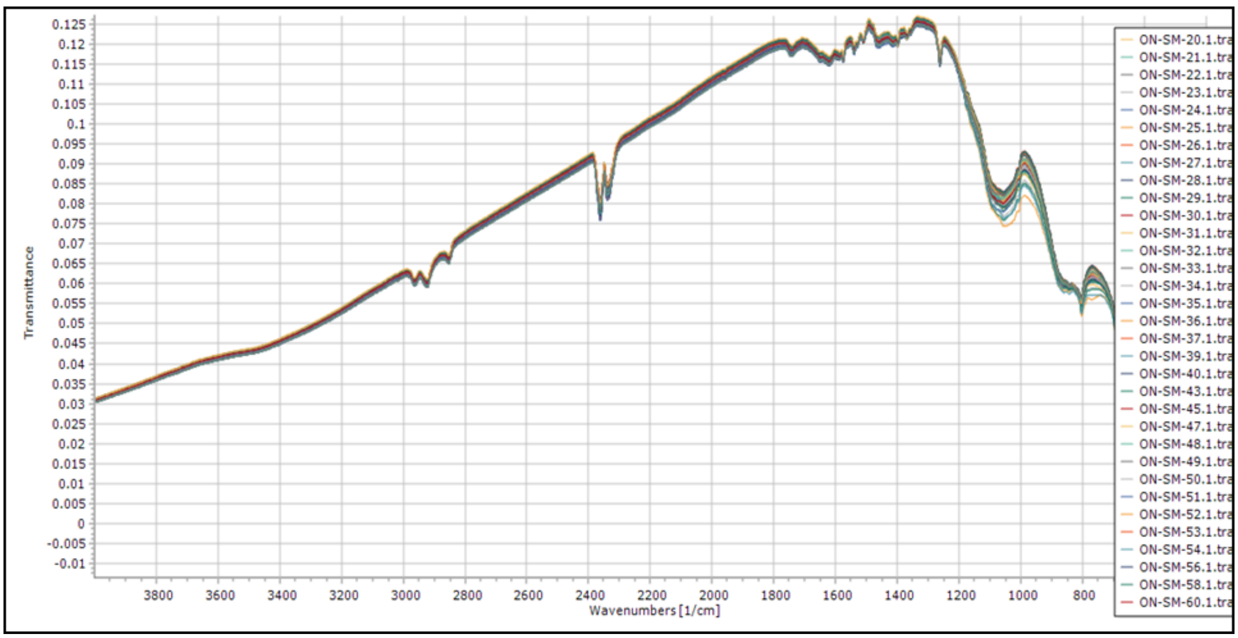

Figure 13. *The FTIR spectra of the raw material samples of the Shuniah Quarry site*

1.4.2 Microscopic Raman Spectroscopy

The micro-Raman did not produce enough resolution to differentiate between the raw material outcrops. The similarity between the spectra produced from the Cummins Quarry and the Shuniah Quarry sites indicates the material is dominated by quartz (Figure 14). However, Raman spectroscopic analysis of the Cummins Quarry site sample ON-CS-04 did indicate the presence of graphene (carbon) oxide which was not present in the sample from the Shuniah Quarry site.

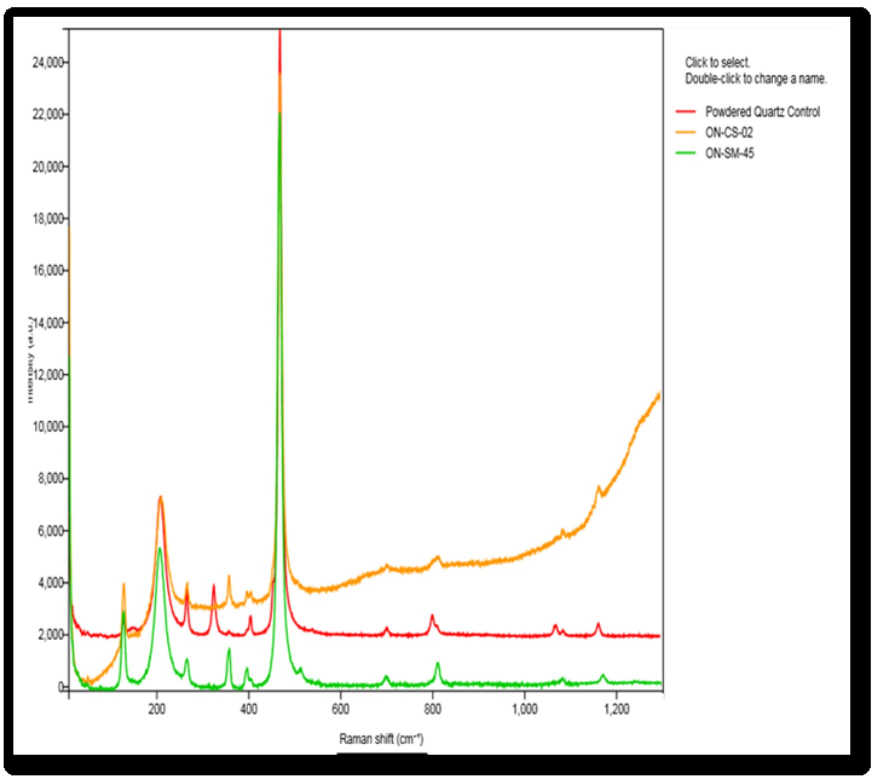

Figure 14. *Raman Spectra of two randomly selected samples from the Cummins and Shuniah Quarry sites from the Gunflint Formation, compared to a reference sample of pure Silicon Dioxide (quartz)*

1.4.3 Portable X-ray Fluorescence Spectroscopy

The P-XRF will identify the elemental composition based on the spectra and the K peak of each element (Table 4). The P-XRF spectra were very similar between each sample from each site (Figure 14). The qualitative elemental profile of the raw material samples from the Cummins Quarry site were identical (Table 5). Likewise, the elemental profile of the raw material samples from the Shuniah Quarry site were also the same (Table 5). All the samples indicated a high concentration of iron and silica (Table 5). Some of the trace elements found in lower concentrations were sulfur, potassium, calcium, titanium, and nickel (Table 5). These elements are common in all of the lithic materials from the Gunflint Formation. The samples from the Shuniah Quarry site included some elements that were not identified in the Cummins Quarry site, these were, aluminum, copper, zinc, and manganese (Table 5).

Table 4 *The K peak position used for the identification of each element*

Element	**K Peak Location in (kV)**
Silicon (Si)	1.74
Sulfur (S)	2.32
Potassium (K)	3.32
Calcium (Ca)	3.69
Titanium (Ti)	4.51
Iron (Fe)	6.39
Nickle (Ni)	7.48
Aluminum (Al)*	1.48
Copper *(Cu)	8.02
Zinc *(Zn)	9.59
Manganese *(Mn)	5.90

* Elements found in higher concentrations at Shuniah Mines Sites

***Table 5** Elemental analysis of lithic samples from the Gunflint Formation and Crane Site Bifaces*

Sample	Site	Fe	Si	S	K	Ca	Ti	Ni	Al	Cu	Zn	Mn
ON-SM-56	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-53	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-51	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-50	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-49	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-48	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-45	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-43	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-40	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-39	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-37	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-36	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-35	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-34	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-32	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-30	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-29	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-28	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-27	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-26	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-25	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-24	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-23	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-22	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-21	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-20	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-19	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-17	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-15	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-14	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-08	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-05	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-SM-03	Shuniah	++	++	+	+	+	+	+	+	+	+	+
ON-CS-12	Cummins	++	++	+	+	+	+	+				
ON-CS-10	Cummins	++	++	+	+	+	+	+				
ON-CS-09	Cummins	++	++	+	+	+	+	+				
ON-CS-08	Cummins	++	++	+	+	+	+	+				
ON-CS-06	Cummins	++	++	+	+	+	+	+				
ON-CS-05	Cummins	++	++	+	+	+	+	+				
ON-CS-04	Cummins	++	++	+	+	+	+	+				
ON-CS-03	Cummins	++	++	+	+	+	+	+				
ON-CS-02	Cummins	++	++	+	+	+	+	+				
ON-CS-01	Cummins	++	++	+	+	+	+	+				
Biface-BB1	Crane	++	++	+	+	+	+	+				
Biface-51	Crane	++	++	+	+	+	+	+				
Biface-44	Crane	++	++	+	+	+	+	+				
Biface-42	Crane	++	++	+	+	+	+	+				
Biface-31	Crane	++	++	+	+	+	+	+				
Biface-12	Crane	++	++	+	+	+	+	+				
Biface-Sur1	Crane	++	++	+	+	+	+	+				

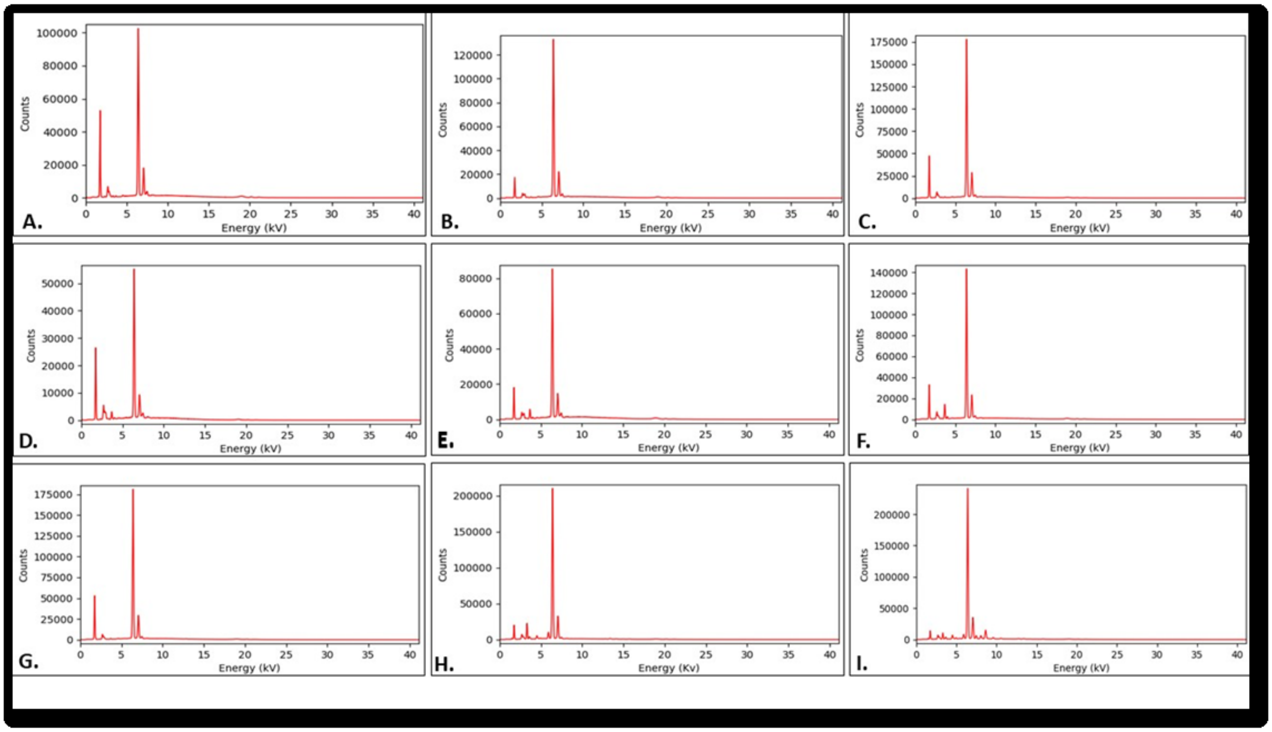

Table 6. *P-XRF Data (A) Crane Biface; (B) Crane Biface; (C) Randomly Selected Cummins Site Lithic Sample; (D) ON-CS-04; (E) ON-CS-12; (F) Randomly Selected Cummins Site Lithic Material; (G) ON-SM-65; (H) Randomly Selected Shuniah Site Lithic Material; (I) Randomly Selected Shuniah Site Lithic Material.*

1.4.4 Macroscopic Identification Methodologies

A principal component analysis was performed on some of the physical characteristics. For the analysis on gloss and translucency there was no significant correlation (Figure 15) but there was a correlation for the average force required to generate a flake and the minimum force required to generate a flake (Figure 16).

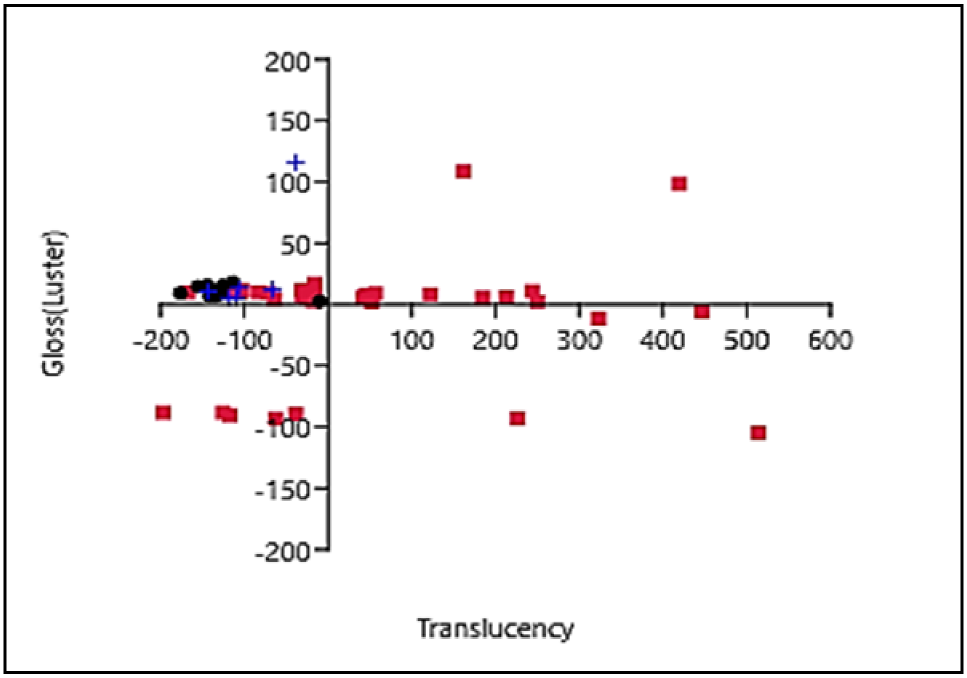

Figure 15. *Principal component analysis with gloss and translucency as the most dominant variables. Blue crosses are the Crane bifaces, red squares are the Shuniah Quarry samples and black circles are the Cummins site samples.*

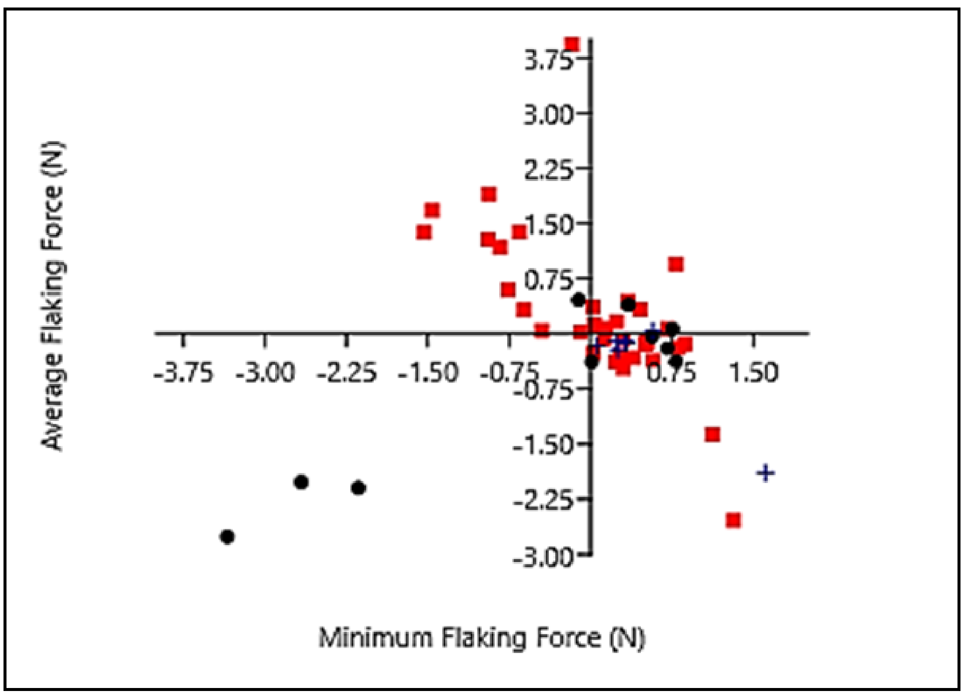

Figure 16. *Principal component analysis with average force required to generate a flake (N) and the minimum amount of force required to remove a flake (N) as the most dominant variables. Blue crosses are the Crane bifaces, red squares are the Shuniah Quarry samples and black circles are the Cummins site samples.*

1.5 Discussion

The use of FTIR, which has primarily been used on organic materials such as archaeological residues, was found to be inconclusive when applied to lithic characterisation. The spectra generated from the lithic samples were identical suggesting that the FTIR analysis was dominated by peaks that were associated with lithic samples. However these peaks could not be ruled out as contamination. The application of FTIR to lithic characterisation may require further investigation.

Regarding FTIR, it is perhaps best to explain why the results were inconclusive in the case of its use with this formation. Firstly, would be the detection limits of the methodology, inorganic bonds tend to peak at the lower fringes of the detection limits of FTIR, for example the peak of a magnetite bond is typically around 638 cm^{-1} another form of iron oxide spectra begins to show peaks below the detection limits of 500 cm^{-1} (Namduri and Nasrazadani 2008). Therefore because a considerable amount of spectral data, which can be used for analysis is below detection limits this methodology is perhaps better suited for addressing other questions, such as those related to investigating organic archaeological residues which may be present on the artefacts.

The Raman spectroscopy produced similar spectra of two very physically different materials. These spectra identified that the material is predominantly made of quartz. This data suggests that the quartz in the samples are producing a signal that is masking other possible chemical compounds that may be present. Therefore, Raman spectroscopy may not be effective in characterising lithic material with a high amount of quartz. However, Raman spectroscopic analysis of the Cummins Quarry site (ON-CS-04) sample did identify the presence of graphite which was not present in the sample from the Shuniah Quarry site. This graphite can be explained by the presence of cyanobacteria which are present in some samples of the Gunflint Formation material (Schopf et al. 2002). Further investigation focusing on changing the parameters of Raman spectroscopy to manage the dominance of quartz in the spectra may improve this technique for the application to lithic characterisation. Although, micro-Raman spectroscopy was limited in its utility to differentiate between the lithic raw materials, it did show more potential with the ability to assess the characteristics of a very small area on the tool. This may prove useful also for archaeological discussions investigating organic residues found on stone tools (Matheson and McCollum 2014; Smith and Clark 2004), as any identification of quartz can be determined as a background signature of the siliceous material.

The best method for the non-destructive analysis of lithic material in this study was the use of P-XRF, which showed that the elemental analysis of the samples in this study contained high concentrations of iron and silicon. For some lithic material made of jasper, this result validates the accuracy of this method. The trace elements, those found in lower concentrations, were more helpful in characterising samples. Some of the trace elements found in lower concentrations were sulfur, potassium, calcium, titanium, and nickel. These elements are common in all of the lithic materials from the Gunflint Formation. However, the raw materials from the Shuniah Quarry site contained trace elements, which were not found in the Cummins Quarry site raw materials or other sites from the southwest portions of the Gunflint Formation, these were aluminum, copper, zinc, and manganese. These trace elements produced a difference between the Shuniah and Cummins Quarry sites that may allow lithic materials to be sourced using P-XRF. The raw materials tested all had similar trace elements present but only the samples from the Shuniah Quarry site contained aluminum, copper, zinc and manganese. Chalcopyrite which is a copper-iron based mineral was visible in some samples which derive from the Gunflint Formation especially with respect to those that are closest to the Shuniah Quarry site. The presence of zinc, and aluminum is harder to explain. It is unlikely to be a residue from the sample preparation processes, which involved cutting the material as it would have also been present in all samples. Also, examples of X-ray diffraction spectroscopy conducted in previous research did not show the presences of these two elements in the minerals detected (Floran and Papike 1978). More work is needed to determine if these elements are actually viable for any sort of sourcing within the Gunflint Formation. Yet, they do show some promise of determining the likelihood of which end of the Gunflint Formation a lithic tool may have derived.

The comparison of the elemental analysis indicate that the lithic biface samples from the Crane site are more likely to have come from the Cummins Quarry site rather than the Shuniah Quarry site. The absence of aluminum, copper, zinc and manganese in the elemental analysis the biface samples tested is consistent with the raw material from the Cummins Quarry site.

The principal component analysis of the macroscopic and physical characteristics of the samples, suggests that there is a differences in the general appearance of some of the lithic raw materials, which derive from each outcrop. However, there was a certain degree of overlap, which is to be expected in the analysis of quarries from one formation. Sourcing, using colour, gloss, translucency, and the forces of flaking demonstrates that sample characteristics plot closely together from the two quarries. However, the degree of overlap between the characteristics of the Cummins and Shuniah Quarry sites makes it too difficult to associate with a high degree of confidence the bifaces of the Crane site to either archaeological site. However, chemical analysis shows that the Cummins site would be more plausible source location. There is one outlier in the Crane site, the banded chert biface (Kakabeka chert), which was the most macroscopically and physically different. Finding this outlier, suggests that differences between the macroscopic and physical characteristics may provide an accurate means of at least sorting large groups of lithic material, if its application to sourcing cannot be achieved.

It is important to note that the gloss of a material can change through post depositional forces. This is why the principle component analysis used excluded the variable of gloss, while using the average force required to generate a flake and minimum force required to generate a flake for the principal components, the results were similar to the analysis with gloss included. However, the analysis with the gloss characteristic excluded, caused the samples from the Cummins Quarry site to plot much differently. The dispersion of the Cummins Quarry site material is likely a reflection of its translucency, which on a whole was more variable than the raw material from the Shuniah Quarry site and Crane site.

1.6 Conclusion

Sourcing sedimentary lithic material using both macroscopic and chemical analysis is possible, which can give an indication of approximately where in a formation a specific artifact could have been quarried. However, the inference needs to be cautiously evaluated since there is an overlap of the characteristics both chemically and visually. The resolution of sedimentary lithic sourcing is best suited to the identification at the formation level and less so at the outcrop level. Chemical analysis in the case of sourcing to a formation level may not be necessary if the quantitative macroscopic approach is used. The chemical analysis may be expensive, but the quantitative macroscopic approach is time consuming. Both approaches have limitations but when used together, can produce accurate results for sourcing lithic material at least to the formation level.

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Chapter 5

Conclusion

The preceding papers represent an analysis of the selection pressures influencing ancient peoples who at the quarry made decisions of what material they wished to collect and manufacture into stone implements. Beginning with the first paper a methodology which aims to identify a better way to articulate the working and flaking characteristics of a raw material was described. This methodology demonstrated that the characteristics of flaking of a material can be variable at specific quarry locations. The next paper aimed to apply the flaking characteristics data to the overall macroscopic appearance of some local bifaces in an effort to identify any statistical relationships which may be present. A secondary aim of the second paper was to also determine if the appearance of a material had an influence on its flaking characteristics. The final paper tried to evaluate a possible source location for a local biface cache using all the collected data from the previous two papers. The information forthcoming will provide a brief summary of each test procedure implemented as well as provide suggestions on how this methodological approach can fit into future studies related to lithics.

This research and the presented papers serve as a guideline for the identification and analysis for lithic materials that is currently being used in Northwestern Ontario. This guideline is built off previous methodological approaches to understanding lithic materials. A simple methodological flowchart is presented which outlines the approach which works well in the study area. A methodological approach for the analysis of lithic material study region especially regarding sedimentary lithic material (Figure 17).

Firstly, there are actually two approaches that were used in the study; one for archaeological material and another for the reference raw material that was used for comparative analysis. The differing approaches were implemented to address the limitations of utilising archeological material for destructive analysis. In some cases, such as when investigating how a raw material propagates flakes or when investigating the mineralogy of a material, destructive analysis is required. Obviously conducting such research on archaeological material would not be advisable unless the researcher, curator and custodian of the artifacts are comfortable with destructive analysis. However, when it is applied to non-archaeological reference material it can provide a strong augmentation to any archaeological hypothesis related to the study of raw lithic materials.

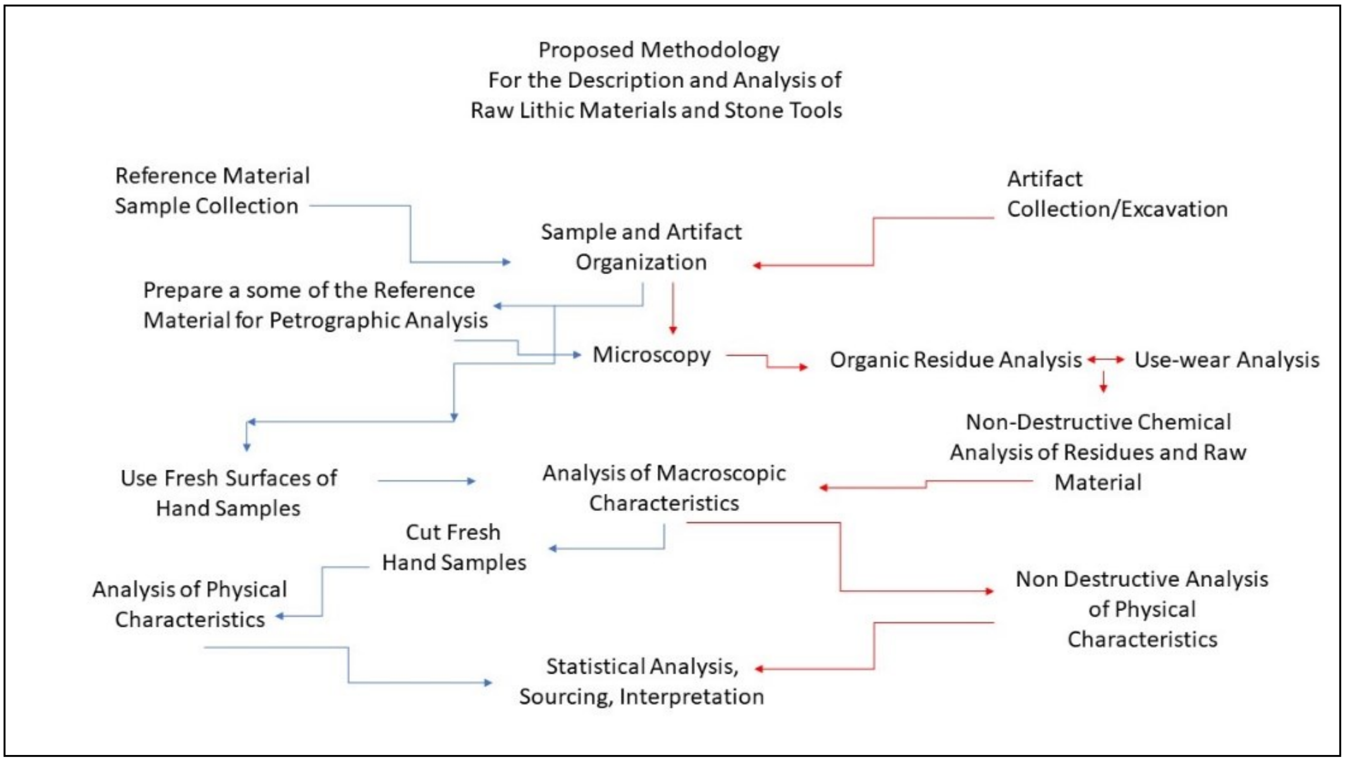

Figure 17. *A flowchart of the possible steps which could be implemented in other study locations.*

The methodological approach starts with sample collection and organisation. Sample collection will apply to archaeological material and reference material. Archaeological samples are very much dependant on the site and the project. Building reference collections can be the most challenging task, as it requires finding source locations. Primary sources are easier to find as they are represented by rock outcroppings. Many possible primary sources can be identified by reading archaeological and geological literature. Secondary sources, at least in North America, can be found in a multitude of locations. The most common locations are close to glacial features in Northwestern Ontario. Identifying secondary sources usually requires a good sense of the local geography and geology. However, there is no guarantee that the location was in fact a primary or secondary source that was exploited by people in the past, unless related archeological material is found in context at the source location. Yet, it is advisable to conduct site visits to confirm the location as a potential source or site, since, what is described in the literature may not necessarily represent an intact ancient quarry location.

Moving on to sample preparation, artifacts are likely to be curated in a standardized way, however cleaning samples should wait until after the organic archaeological residue and use wear analysis have been conducted. Usually this involves first employing microscopy to identify areas of interest. Reference Materials need to be prepared for analysis focusing on a fresh surface of the raw material. When exposing a fresh unweathered surface, using traditional percussive flaking techniques are best, akin to the approach used by experimental archaeologists and flintknappers. The researcher can get a sense of the characteristics of the raw material while producing a fresh surface for analysis and the debitage, i.e. extra material, can be used to generate mineralogical thin sections for petrographic analysis.

Microscopy is the next logical step with artifacts, as you can identify areas of interest for further study. With the reference material, one is able to get a good sense of the mineralogy, which makes chemical analysis more effective and efficient by providing the researcher with a sense of the chemistry of the material before it is tested. In addition, the added foresight allows for the identification of possible sample contamination. How a material can propagate flakes can also be determined with petrographic analysis. Petrographic slides of the material allows for a detailed examination of the microscopic boundaries of crystalline transitions, for example the examination of crystalline boundaries provides easy differentiation and identification between a chalcedony and a chert. In the case of the Gunflint Formation petrography was useful for determining the transitions between grains of hematite/magnetite and its boundary between chert/chalcedony. Petrography concludes the microscopic techniques now the analysis of macroscopic characteristics can be evaluated.

After microscopy, the ideal approach would be to conduct both organic residue analysis and use wear analysis. The steps of organic residue and use wear analysis are important for the holistic understanding of a raw material, how it has been manufactured into a tool and how it has been used. Approaching archaeological hypotheses related to raw material selection processes in this way, can illuminate the possible purposes of the final product and address questions of how selection was influenced by the raw material itself. For the purposes of future chemical analysis of a raw material, organic residue analysis can provide a sense of possible contamination to the elemental analysis of the raw material.

Non-Destructive Chemical analysis can now be used to interpret possible source locations for a raw material. In the case of the Gunflint Formation it was noted that Raman Spectroscopy, FTIR, and XRF added additional information however, XRF produced the most informative data. Although the combination between Raman Spectroscopy and XRF seems promising there is still work to do on overcoming the limitations of detecting the bonds of trace elements over the noise of the Silica bonds. In terms of sedimentary rocks, the archaeologist must understand that they are dealing with marine and aquatic chemistry. In addition, there is also the complicated natural chemical processes of diagenesis related to siliceous sedimentary rocks. With the Gunflint Formation other challenges includes dealing with a large geologic formation, which due to its Precambrian age has a large and complex geological history.

Moving on to identifying the macroscopic characteristics of a material in both the raw material and archaeological material can now be conducted. These characteristics can be tested in any order, but during this research the most time consuming analysis was conducted first. The colour analysis of samples began with highly detailed photography, under controlled conditions. The results were then digitized which allowed for a more effective statistical analysis, the data was then converted to the Munsell system for consistency with current methodological approaches employed by archaeologists and geologist. The next visual characteristic examined was the Luster measurement using a glossmeter. This was then followed by the translucency method. These visual characteristics may provide insight into many facets of archaeological hypotheses relating to both culture and physical properties of the material.

Raw material samples need to be cut into blocks to examine the flaking properties. These flaking properties have traditionally been limited to pressure flaking, by generating a consistent and reliable methodology to characterise and identify raw materials for source archaeological material contributes greatly to archaeology. However, further investigation with these and other techniques may improve this presented approach (Figure 17). Cutting the raw material into equal and consistent samples reduces the effect of the natural flaws of a material. Damaging archaeological material is obviously not advisable, however by using reference samples many interpolations can be made with respect to the flaking properties of a material and its final product.

Finally the collection of the data can be analysed by the use of statistical methods. Archaeological hypotheses related to collection of lithic raw materials can now be tested using a range of data collected using the aforementioned methodological approach. Incorporating raw material analysis alongside traditional archaeological methodologies such as lithic sourcing, use wear and organic residue analysis a very comprehensive understanding of selection pressures of raw materials can be better understood.

Moving forward, many of these methods such as quantification of colour, luster, and translucency have demonstrated an effective means of sorting large amounts of materials, and when combined with chemical analysis, such as P-XRF some arguments regarding sourcing material within a formation to specific outcrops can be developed.

Attributes such as luster and translucency did not appear to show any significant statistical correlation when compared to flaking properties, at least within the sample set. Colour may so some correlation to flaking properties reflecting the mineral assemblage of a raw material but, one cannot rule of the possibility of a colour(s) aesthetic value as a cultural selection pressure. In future it would be interesting to apply these methods to large sample sets in a large study area with an effort to developing a stronger sense of the diverse lithology of raw materials in North America. Moreover, applying similar studies to a larger historical timeline may present opportunities for better understanding cultural changes overtime with respect to raw materials.

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Appendix

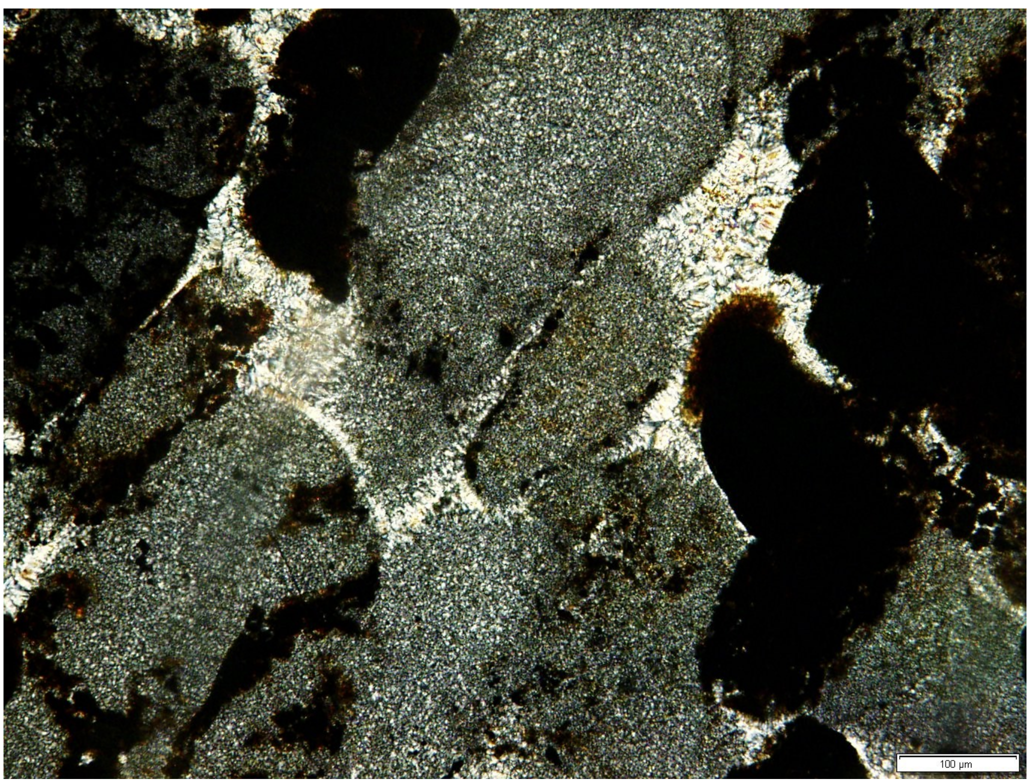
Appendix 1. *Experimental replica knife made to better understand working qualities of jasper taconite*

Appendix 2. *Intact section of the Shuniah Site Quarry (bottom center of photograph)*

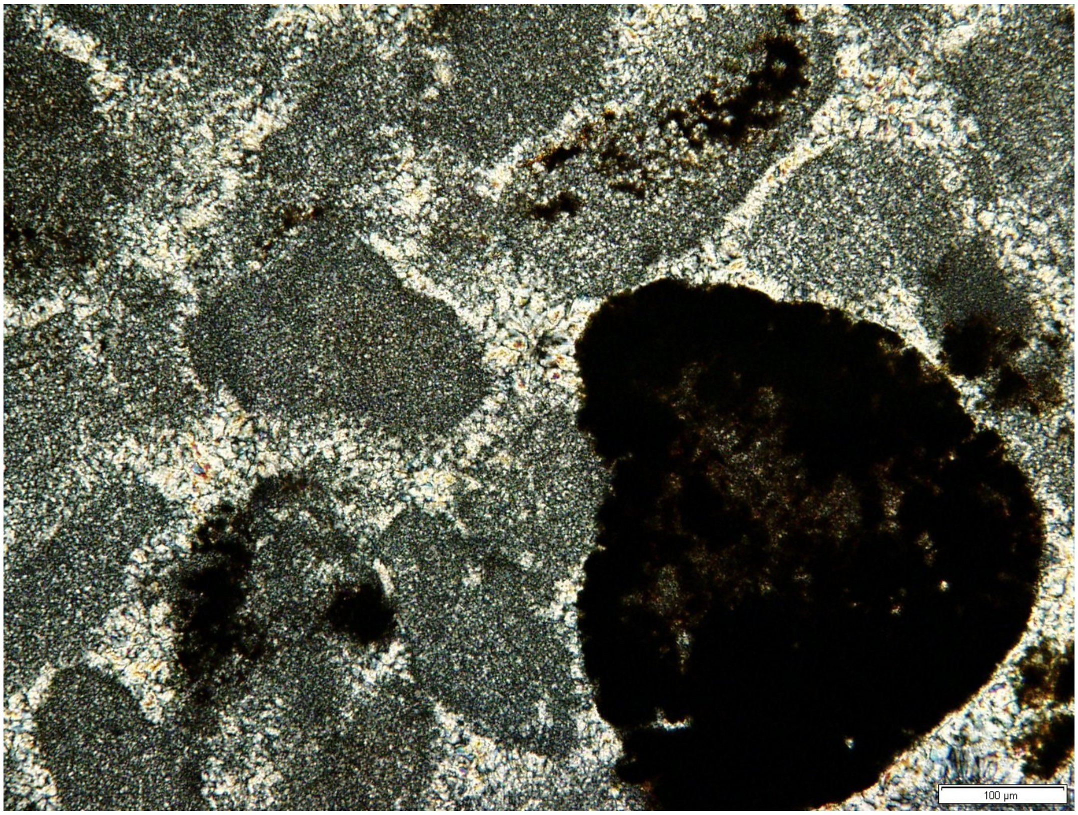
***Appendix 3**. Large primary flake found at the Shuniah Site Quarry during the 2016 revisit.*

***Appendix 4.** Tabular block of jasper taconite found at the Shuniah Quarry site during the 2016 revisit*

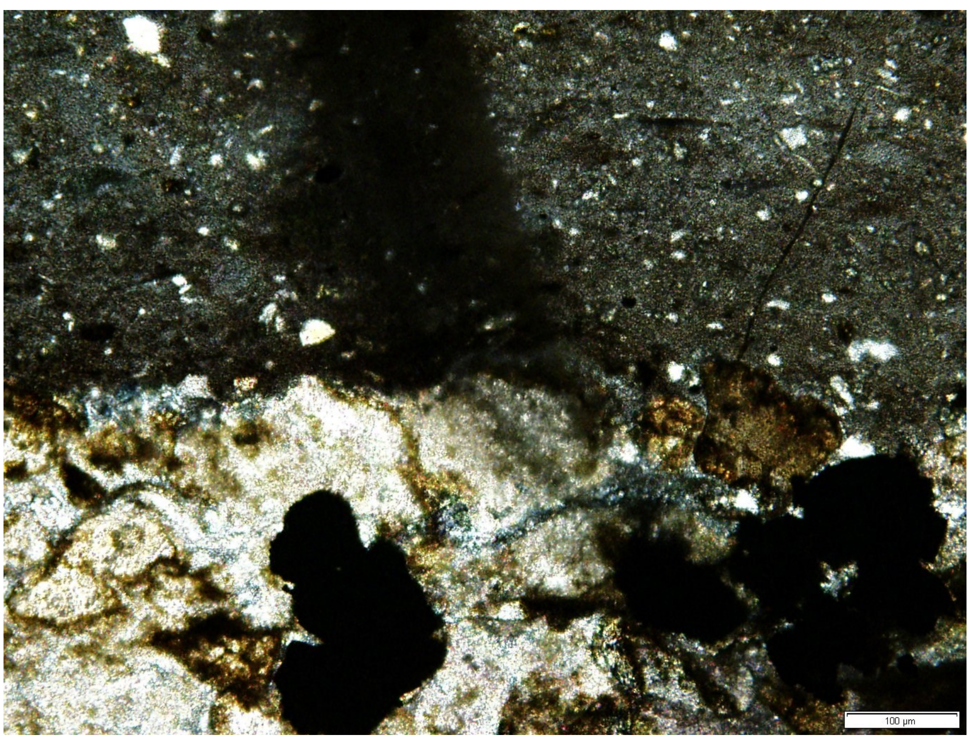
Appendix 4.*Example of typical block of Taconite common at Upper Gunflint Formation outcrops*



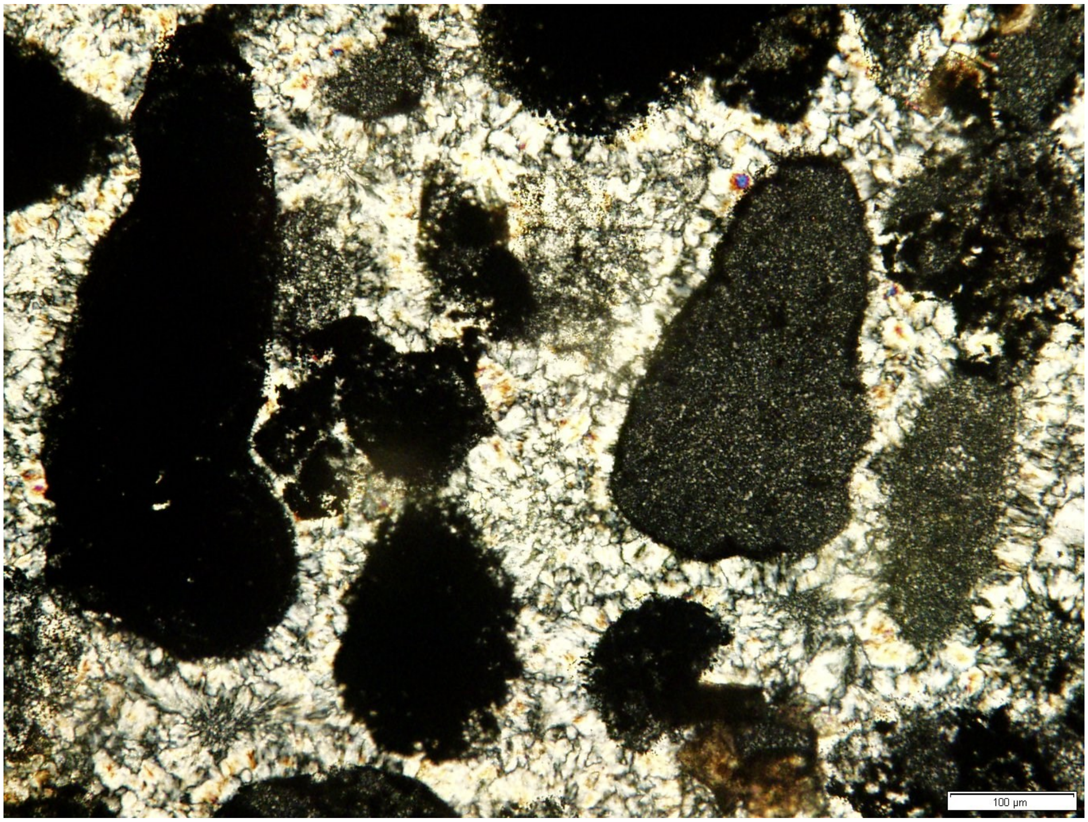
Appendix 5 *Petrographic slide of a darker variety of taconite*



Appendix 6 *Petrographic slide of a reddish variety of taconite (Jasper Taconite)*



Appendix 7 *Petrographic slide of Kakabeka Chert at the boundary of the bands*



Appendix 8 *Petrographic Slide of Gunflint Silica*